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Proceedings

WHEY PRODUCTS CONFERENCE

held at Chicago, Illinois
June 14-15, 1972

EASTERN REGIONAL
RESEARCH LABORATORY

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

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Welcoming Remarks

J. T. Walsh

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M. I. Wegner

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Mr. Walsh:

Whey Processors, Industry Friends, and Guests...

With pleasure, we welcome you to the Whey Products Conference/1972 which is cosponsored by the Whey Products Institute and the U.S. Department of Agriculture, Agricultural Research Service.

Advance registrations and attendance at this conference exceeds original optimistic estimates, and we believe it reflects an ever-increasing interest and determination to assure a developing, progressive--and profitable--future for the whey industry through new and expanding utilization of whey and products of whey.

In retrospect, it would appear that there is a thread of significance between the month of June and whey industry developments. You will recall that the first conference, called the Whey Utilization Conference, was organized by the Agricultural Research Service and held in June 1970 at the University of Maryland. The result of that conference was the expressed and recognized need for U.S. whey processors to work together and gain recognition as an industry entity to further the utilization of whey and whey products. This recognized need culminated in the founding of the Whey Products Institute in June 1971.

The Whey Products Institute, since its formation just one year ago, has gained recognition as a sound, effective industry organization as a result of the work and services initiated to date in behalf of its membership.

Through the functioning of its standing committees, the work initiated to date includes: development of proposed "standards of identity/definitions" and "extra" grade product specifications for the principal types of whey and modifications thereof; recommended plant sanitation code for the manufacture of edible-quality whey products; review and investigation of certain methods of analysis in ascertaining quality characteristics of dry wheys; developing programs for market and product studies for the utilization of whey and whey products; review of proposed research projects, including particular consideration of questions pertaining to "lactose intolerance"; and the abatement and elimination of whey disposal, as such, to the environment.

It is obvious that the whey industry is confronted by numerous and complex problems, but a start has been made down the road leading to new horizons. As we gain in knowledge of the functional characteristics and nutritional contributions of whey products, we shall gain the confidence required to solve our industry problems. As we can, we shall turn this new knowledge and confidence into opportunity.

And now we come to June 1972, and the Whey Products Conference now getting underway. The program for this 1972 conference is comprehensive and encompassing in the subjects relating to whey that are to be presented by guest speakers knowledgeable in their field of expertise--in economics, technology, research, and product utilization. In fact, the program is not unlike Playboy magazine--it contains something of interest for everyone, in a whey!

It is noteworthy that we have present at this conference a number of representatives from Canada, England, and New Zealand. We greatly appreciate the distances they have traveled and the time they have taken to be with us.

It is my privilege to share these initial moments of the program with Dr. M. I. Wegner, Assistant Director, Eastern Marketing and Nutrition Research Division of the U.S. Department of Agriculture.

Dr. Wegner:

Speaking for the Eastern Marketing and Nutrition Research Division of the Agricultural Research Service, which is a cosponsor of this conference, I am indeed pleased to welcome all of you. I also wish to convey to you the welcome and best wishes for a successful conference from Dr. Wolff, Director of our Division, who regretfully is unable to attend due to prior travel commitments that have taken him out of the country.

In a sense, this Whey Products Conference may be considered a reconvened meeting of the first Whey Utilization Conference sponsored by the Eastern Marketing and Nutrition Research Division and held in College Park, Md., in 1970. I say "reconvened" because then we were only in the preliminary stages of finding possible solutions to many of the challenging and vexing problems of whey utilization we discussed. Today we listen with anticipation to reports on the progress of these solutions.

The goals and efforts of this conference continue to be those so aptly expressed at the first conference. In simple terms, the problems of whey utilization constitute a part of the mosaic of the increased stresses our affluent society is placing on our ecosystem, a system which we have been made to realize has a finite capacity for insult. With this realization, the urgency to cope with environmental pollution by whey is quite apparent. Since the whole of society is involved, the problems affect not just you, or you, or you, but each one of us. Thus, we can no longer afford the luxury of going it alone. The scope of the problem dictates a unified, concerted effort. And this means the kind of cooperation we had in arranging this conference today--cooperation involving industry, government, and academic institutions. Speaking for the Department of Agriculture, I know I can express its commitment to this objective.

At our Eastern marketing and nutrition laboratories, we have been carrying out for some time an aggressive program in whey utilization and elimination of pollution. Many of you are already acquainted with our work. At this conference, we propose to tell you more about it. Our program on whey utilization is one part of our major on-going research program on milk and dairy products. Since those of you attending from industry generally have allied dairy product operations, I would like to take a moment to acquaint you with several of our developments of new or improved dairy products. One exciting new product is a milk-orange drink we identify by the term MOD. It consists of a blend of milk, orange juice, and minor additives. MOD has a unique protein stability at the acid pH of orange juice which cannot be obtained by simply mixing orange juice and milk. Presently in test market, it may provide one means of halting or reversing the decline in per-capita whole milk consumption.

Another development in which there is wide interest is a new skim-milk semi-soft cheese with low fat content--4 to 7 percent fat as compared to 20 to 34 percent fat in whole-milk cheese. In the dried milk area a foam-spray-dried product prepared from reconstituted milk, using deodorized butteroil and skim milk, provides a product with long-term storage stability at room temperature. When reconstituted to a beverage, it is almost indistinguishable from fresh pasteurized whole milk. The product showed no significant change in flavor after six months' storage at 80° F., when packed with an oxygen scavenger. Another item of special interest to this group is an iron polyphosphate compound which forms a complex with whey protein and has potential for iron enrichment of foods. Animal feeding tests demonstrated the iron to have a high level of absorption and a biological value superior to many compounds presently used in food fortification. When added to foods, it exhibits a minimal effect on flavor as compared to many other forms of iron compounds presently used. We are also conducting research on feeding cows a ration containing encapsulated vegetable oils high in polyunsaturated fatty acids as a means of increasing the P/S ratio of butterfat. Positive results have been achieved with a marked increase in the percentage of linoleic acid. The nutritional aspects of the type and levels of fatty acids in the diet as they relate to coronary heart disease is a subject receiving top billing these days by nutritionists and the medical profession.

The real payoff in these developments is in their commercial application. Therefore, before starting the excellent program planned for us, I want to extend to you all a cordial invitation to visit our laboratories at Wyndmoor, Pa., and Washington, D. C., talk shop with our staff, learn how our programs can benefit you, and alert us to your problems. We want to encourage the same kind of cross-fertilization and cooperation we see here today on whey to work we are doing on all other dairy products.

One final message, Dr. Wolff requested that I assure you of the Eastern Marketing and Nutrition Research Division's endorsement of, and intent to continue sponsoring, future conferences on the utilization of whey.

An Economic Analysis of Whey Utilization

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Whey is becoming an increasingly important stepchild of the dairy industry. As a byproduct of the cheese industry, its greater production along with the increased production of cheese is viewed with interest by different groups of people.

Environmentalists may look at increased whey production with some alarm as a potential pollutant of our rivers and streams. Humanitarians are concerned that such a large percentage of a potential source of excellent protein is wasted. Researchers in universities and industry are looking for new uses for whey and whey derivatives. Some cheese manufacturers, some whey processors, and municipalities are looking for the method of disposal that will involve the least expense or loss. And everybody is looking for a way to turn a product that has been an economic liability for years into profitable end uses.

The following discussion is an updating of some of the information contained in our economic analysis of whey utilization and disposal published in 1965.[1/] No attempt was made to completely duplicate the plant survey or to update processing costs, but information was gathered from a number of people in the industry.

IMPORTANCE OF WHEY IN WISCONSIN

In 1970, Wisconsin produced over 600 million pounds of American cheese--about 46 percent of the Nation's total. Total cheese produced in the State, excluding cottage cheese, was over 900 million pounds (table 1). Since 1960,

[1/] Groves, F. W., and Graf, T. F. An economic analysis of whey utilization and disposal in Wisconsin. Univ. of Wis., College of Agriculture, Dept. of Agricultural Economics. Agr. Econ. 44, 61 pp. 1965.

TABLE 1.--Cheese, liquid whey, and dried whey production in Wisconsin for selected years, 1955-1971[1]

Year	Cheese production		Liquid whey production[2,3]			Dried whey production (thousands of pounds)
	Total (thousands of pounds)	Percentage of 1955 production	Total (thousands of pounds)	Average per factory (thousands of pounds)	Percentage of 1955 average	
1955	598,112	100	5,204,000	4,922	100	69,867
1960	641,499	107	5,581,000	6,994	142	87,495
1965	770,398	129	6,702,000	10,589	215	158,802
1967	828,911	139	7,212,000	12,455	253	222,153
1968	847,007	142	7,369,000	13,595	276	240,577
1969	866,593	145	7,539,000	14,871	302	244,202
1970	947,591	158	8,244,000	17,140	348	292,981
1971	986,369	165	8,581,000	18,736	380	332,900

1/Source: Wisconsin Agricultural Statistics, various issues.
2/Estimated at 8.7 pounds of whey per pound of cheese.
3/Does not include cottage cheese curd or creamed.

cheese production has increased by more than one-third, and dried whey production almost four times.

The proportion of whey that is dried, except that from cottage cheese, has been increasing. In 1955 it was about 27 percent, and in 1971, about 78 percent (table 2). While the amount of whey being dried has been increasing, so has the amount of whey being used directly in blends of different products. Many products are blended before drying, and the raw whey used in these items is not reported as being processed. Consequently, any current reports of processed whey underestimates processing of these blends.

TABLE 2.--Proportion of whey dried in Wisconsin for selected years[1/]

Year	Liquid whey[2,3/] (thousands of pounds)	Dried whey	
		Thousands of pounds	Percent[4/]
1955	5,204,000	69,867	27
1960	5,581,000	87,495	31
1965	6,702,000	158,802	47
1970	8,244,000	292,981	71
1971	8,581,410[5/]	332,800[6/]	78[5/]

1/Source: Wisconsin Agricultural Statistics, various issues.

2/Estimated at 8.7 pounds of whey per pound of cheese.

3/Does not include cottage cheese whey.

4/Calculated by converting dried whey data to liquid basis (20 pounds liquid whey per pound dried whey).

5/From table 4.

6/From table 1.

The number of cheese factories has been declining in Wisconsin for many years. In 1965 there were over 1,200. In 1971 there were less than 500 (table 3). On a percentage basis, the decline has been almost two-thirds. Since the remaining plants are larger than those going out of business, the amount of whey per factory has also been increasing. From 1955 to 1970 the amount of whey per factory more than quadrupled (table 1).

TABLE 3.--Number of dairy plants making cheese in Wisconsin for selected years[1/]

Year	Number	Percent of 1950
1950	1,279	100
1955	1,057	83
1960	798	62
1965	633	50
1967	579	45
1968	542	42
1969	507	40
1970	481	38
1971	458	36

[1/] Source: Wisconsin Dairy Facts 1971 (Wisconsin Statistical Reporting Service).

This greater concentration of whey among fewer factories can have advantages and disadvantages. If satisfactory methods of whey disposal are not available, larger volumes can compound an already sticky problem. On the other hand, if satisfactory alternatives are available, additional supplies of whey can mean greater economic returns. The larger volumes can make it economically feasible to adopt processing techniques not practical for smaller quantities of whey. In other words, if disposal is a problem, additional volumes can increase returns.

SEASONALITY OF WHEY PRODUCTION

Much of the cheese produced in Wisconsin is made from manufacturing grade milk. The seasonal swing of manufacturing milk production is usually wider than the seasonal swing for Grade A milk production. Cheese and whey production follow the wider seasonal pattern, so that processing plants must have the capacity to handle flush volumes or use other disposal methods in flush periods. In 1961, a whey processing plant needed 170 percent of the November capacity to handle the volume in June. An average of 1969-71 showed that the seasonal swing in production had declined to about 160 percent of the high month over the low month.

USES OF WHEY

In 1962, Wisconsin produced almost 7 billion pounds of liquid whey. About 27 percent of this whey was processed into dried whey powder. Small amounts of the remaining whey were used for the production of albumin and other whey derivatives. Lactose was frequently produced in conjunction with dried whey powder.

DISPOSAL METHODS

The most common methods of whey disposal in 1962 were: returning whey free to farmers, dumping it as waste or sewage, selling it to processors, and paying processors to collect it. The proportion of whey that was sold was rather small, and virtually all of it was used in processing products for human consumption.

All of the above methods of disposal are still being used. However, more whey is being processed, and whey disposed of as waste or sewage is less and is more closely regulated than in 1962. As noted, less than 30 percent of the whey could be accounted for in 1962 as being processed. In 1971, less than 10 percent of all whey except that from cottage cheese was unaccounted for--25 percent if all whey is included (table 4). In 1971, 91 percent of the whey except that from cottage cheese was either dried or condensed. However, this estimate of dried whey may be high because undoubtedly some of the condensed whey later ends up as dried whey and may be double counted.

CHANGE IN DISPOSAL METHODS

The change in whey disposal and utilization has been the result of several factors. One is that less whey is being returned to farmers because of the shift to bulk farm pickup and the high cost of operating return routes. In 1962, those plants that estimated a cost of returning whey to farmers felt it was in the range of 1 to 10 cents per hundred pounds (cwt.). The weighted average estimate of cost per cwt. was 2.79 cents. Many factories did not attempt to estimate the cost of returning whey, but knew that it existed because of the labor involved and the cost of maintaining equipment.

Other factors include greater volumes of whey to be handled, increased costs of labor and equipment, and more specialization of agriculture. These have all contributed to a reduction in the whey being returned to the farm. However, whey is still considered an excellent feed, and the University of Wisconsin currently is conducting a research program on using whey in animal feeds.

Increased concern with the environment has led to more rigid enforcement of whey disposal regulations. Less whey is being indiscriminately disposed of, and more is going into municipal and other disposal systems or some kind of processing.

TABLE 4.--Utilization of whey in Wisconsin, 1971[1/]

Item	Thousands of pounds	Percent without cottage cheese	Percent with cottage cheese
Cheese production (excluding cottage cheese)	986,369		
Liquid whey[2/]	8,581,410		
Liquid whey dried[3/]	6,660,000	78	64
Liquid whey condensed[4/]	1,146,000	13	11
Unaccounted	775,410	9	
Cottage cheese whey[5/]	1,800,000		
Total unaccounted	2,575,410		25
Total of all whey	10,381,410	100	100

[1/]Source: Wisconsin Crop Reporting Board.

[2/]Estimated at 8.7 pounds of whey per pound of cheese.

[3/]Liquid equivalent of approximately 429,000,000 pounds of dried whey (20 pounds of liquid whey per pound of dried whey).

[4/]Liquid equivalent of approximately 191,000,000 pounds of condensed whey, 30 percent solids (57,300,000 pounds of whey solids x 20 pounds of liquid whey per pound of solids). Some of this whey may be dried, but the amount is unknown.

[5/]Based on cottage cheese production of 40,000,000 pounds.

FIELD DISPOSAL

Some whey was being disposed of by spreading on fields for fertilizer in 1962. At that time the value of the plant nutrients was estimated at about 4.0 cents per cwt. Using a ratio of three tons of whey being equal in plant nutrients to a ton of manure, whey is worth about 3.3 cents per cwt. today for fertilizer. Some research had been done on the application of whey to certain pasture and field crops. The Soil Science Department at the University of Wisconsin is currently conducting research on the amount of whey that can be absorbed in different types of soil and that can be tolerated by different crops.

The same problems in field disposal exist today as in 1962. The land is unable to absorb excess quantities of whey, microorganisms and certain crops are unable to effectively convert and use excess quantities of whey, and the flush in whey production coincides with periods when it is often difficult or impossible to get the whey on the land or for the whey to soak into the ground.

SMALL PLANT DISPOSAL

The small cheese factory is still in a disadvantageous position in whey disposal. Its volume is too small to justify the installation of disposal or processing equipment. It is often uneconomic to install the kind of equipment necessary to ensure that the whey is cooled and handled as required for later use for human consumption. One alternative is to join with other factories and set up some type of processing or disposal system. Those continuing to dump or field-spread whey are frequently subject to strict regulation.

A number of small plants set up roller drying facilities in the early 1960's. Some of these have now gone out of existence, and roller drying is less important. The trend to more stringent sanitary conditions, and use of more whey in human foods, have contributed to the decline in roller drying.

Cheesemakers that have no other viable economic alternative are still paying to have whey hauled from the factory. In 1962, processors were being paid to dispose of the whey from over 150 Wisconsin plants.

WHEY PROCESSING

No attempt has been made to update the processing costs that were estimated in 1965. Costs of all processing components, with the exception of the whey, have increased considerably.

For example, since 1962, construction costs are up 53 percent, machinery and equipment costs up 25 percent, average hourly earnings up 44 percent, and contract construction up 73 percent. All of this has occurred while the price for dried whey has remained relatively constant.

As noted, roller drying is not as common as in 1961, and more of the dried whey qualifies as being eligible for human consumption. Spray drying continues to be the most important drying method, but new innovations in drying and processing are gaining in importance.

Dried whey is still a product of last resort and one of small profit. Whey proteins, lactose, and blended and specialty products are more profitable than dried whey.

WHEY MARKETING

Large whey processors usually sell their products directly to the end user through their own sales organizations. Smaller processors usually sell through regional sales organizationswith which they are affiliated and in some cases through brokers.

The overall market for whey products has been expanding. New uses have been developed, both as a food and for certain industrial processes. There is more interest in breaking whey down into its component parts and then using the parts in other foods.

While a whey parket as such does not exist, some estimates of relative return can be made. Processors indicate that blended products and those using component parts of whey are more profitable than whole dried whey. However, the returns from dried whey are often better than other disposal methods. For example, whey drying may be a break-even operation, while the next alternative may result in a net loss.

At the present time there is a lack of uniform standards for use throughout the whey industry. This may work to the advantage of some processors but it is to the overall disadvantage of the industry. It makes it difficult to estimate the volume of different uses of whey, and it complicates the comparison of whey products by potential buyers. Hopefully this situation will be corrected in the next few years.

WHEY PRICES

Prices of dried whey (animal feed) have been relatively stable for the past 15 years. In 1955, the price of animal feed was 5.53 cents per pound in Chicago; in 1970 the price was 5.68 cents, and in 1971, 4.99 cents (table 5). During the same period the price of nonfat dried milk was quite stable until 1966. From 1966 to 1971, the price of nonfat dried milk more than doubled.

Prices for food-grade whey powder have not been generally reported until the last few years. Prices in Eastern areas for food-grade dried whey were generally 2 to 3 cents per pound above the price of animal feed from 1965 to 1970 (table 5).

Monthly average prices in Wisconsin are shown in table 6. Comparison prices for nonfat dried milk are also shown.

The difference in price between whey for animal feed, spray- and roller-dried, and edible whey is shown in table 7. Spray-dried animal feed whey ranged from less than one cent per pound difference to slightly over 2 cents per pound. The differences were greater between roller-dried feed whey and edible whey. On a percentage basis the edible whey ranged from about 115 percent to over 200 percent of the animal-feed whey prices.

TABLE 5.--Prices for nonfat dried milk, F.O.B. factory, for feed-grade dried whey in Chicago, and for whey powder for human food in Eastern areas, 1955-1971[1/]

Year	Price of nonfat dried milk for human food, F.O.B. factory (cents per lb.)	Dried whey, wholesale price in trucklots (cents per lb.)	
		Animal feed, Chicago	Human food, Eastern areas
1955	15.35	5.53	
1956	15.24	5.68	
1957	15.29	5.51	
1958	14.09	5.61	
1959	13.60	5.60	
1960	13.66	5.60	
1961	15.45	5.26	
1962	14.79	5.25	
1963	14.43	5.42	
1964	14.62	5.35	
1965	14.66	5.18	7.89
1966	18.19	6.15	9.12
1967	19.92	6.02	9.25
1968	22.36	5.02	8.68
1969	23.50	5.28	8.05
1970	27.3	5.68	7.83
1971	30.7	4.99	

[1/] Source: The Dairy Situation, various issues.

TABLE 6.--Monthly average prices for dried whey and nonfat dried milk in Wisconsin, June 1970 to April 1972[1/]

Month and Year	Dried whey			Nonfat dried milk		
	Human feed	Animal feed		High heat	Low heat	Grade A
	Spray	Spray	Roller			
1970:						
June	6.67	5.26	4.38	27.74	28.25	-
July	6.63	5.52	4.41	27.74	28.25	-
Aug.	6.52	5.50	4.48	27.68	27.77	28.91
Sept.	6.40	5.56	4.68	27.68	27.68	28.93
Oct.	6.63	5.73	4.86	27.68	27.68	28.93
Nov.	6.81	5.78	4.90	27.68	27.68	28.93
Dec.	6.86	5.88	4.90	27.68	27.68	28.93
1971:						
Jan.	6.53	5.25	4.79	27.68	27.68	28.93
Feb.	6.31	4.84	4.45	27.58	27.64	28.93
March	6.08	4.75	4.14	27.55	27.68	28.93
April	6.03	4.61	3.94	31.89	31.89	33.43
May	6.00	4.53	3.75	32.05	32.05	33.43
June	6.00	4.53	3.66	32.05	32.05	33.43
July	6.70	4.63	3.63	32.05	32.16	33.43
Aug.	6.88	4.81	3.64	31.71	32.20	33.43
Sept.	6.88	5.00	3.36	31.50	32.08	33.41
Oct.	6.88	5.00	3.78	31.50	32.08	33.43
Nov.	7.13	5.00	4.07	31.50	32.08	33.43
Dec.	7.18	5.33	4.39	31.63	32.08	33.43
1972:						
Jan.	7.25	5.38	4.48	31.72	32.16	33.43
Feb.	7.25	5.63	4.50	31.75	32.25	33.43
March	7.33	5.68	4.51	31.68	32.24	33.38
April	7.23	5.50	4.58	31.63	32.23	33.35

[1/] Source: Monthly Cold Storage Report, Wisconsin Department of Agriculture.

TABLE 7.--Price differential between spray- and roller-dried whey for animal feed and whey powder for human food in cents per pound and percent, in Wisconsin, June 1970 to April 1972[1/]

Month and Year	Excess in price of edible whey powder			
	Over spray-dried whey for feed		Over roller-dried whey for feed	
	Cents per pound	Percent	Cents per pound	Percent
1970:				
June	1.41	126.81	2.29	152.28
July	1.11	120.11	2.22	150.34
Aug.	1.02	118.54	2.04	145.54
Sept.	.84	115.11	1.72	136.75
Oct.	.90	115.71	1.77	136.42
Nov.	1.03	117.82	1.91	138.98
Dec.	.98	116.67	1.96	140.00
1971:				
Jan.	1.28	124.38	1.74	136.32
Feb.	1.47	130.37	1.86	141.80
March	1.33	128.00	1.94	146.86
April	1.42	130.80	2.09	153.04
May	1.47	132.45	2.25	160.00
June	1.47	132.45	2.34	163.93
July	2.07	144.71	3.07	184.57
Aug.	2.07	143.04	3.24	189.01
Sept.	1.88	137.60	3.52	204.76
Oct.	1.88	182.01	3.10	182.01
Nov.	2.13	142.60	3.06	175.18
Dec.	1.85	134.71	2.79	163.55
1972:				
Jan.	1.87	134.76	2.77	161.83
Feb.	1.62	128.77	2.75	161.11
March	1.65	129.05	2.82	162.53
April	1.73	131.45	2.65	157.86

[1/] Source: Calculated from data appearing in the Monthly Cold Storage Report of the Dairy and Poultry Market News issued by Federal-State Market News Service, USDA.

FUTURE FOR WHEY

The amount of whey available for processing is bound to increase as the proportion and absolute volume of milk used in cheese increase. In 1955, about 25 percent of the total United States milk supply was used in butter and 11 percent in cheese. By 1965, 23 percent was used in butter and 13 percent in cheese, and in 1969, 21 percent was used in butter and over 15 percent in cheese. In 1971, only about 3 billion pounds more milk was made into butter than was made into cheese: 21 billion pounds went into cheese and about 24 billion pounds into butter. If this trend continues, and at this time there is little reason to doubt that it will, the percentage of milk used in cheese will exceed that used in butter within the next two to three years.

The U.S. Department of Agriculture has estimated that there will be an additional 750 million pounds of whey solids within the next three years. This will mean a doubling of the size of the present whey processing industry.

Production of butter in Wisconsin has been steadily declining as plants have shifted out of butter-powder and into cheese. In 1969, the production of dried whey in Wisconsin exceeded the production of nonfat dried milk for the first time (table 8).

Milk production has been declining in some areas and increasing in others. Consequently, production is being concentrated in certain parts of the country, primarily the major dairy areas in the East, Midwest and West. For example, Wisconsin produced over 17 percent of the Nation's milk supply in 1970, and will probably produce 19-20 percent by 1980.

By 1980, pressures to use whey in an economical manner and not treat it as waste or sewage will increase. This will take the form of more rigid regulations for land and sewage disposal, and more research for new whey products, both industrial and food.

There is likely to be more regulation and standardization of whey products than there has been in the past. Better reporting of utilization will be required, both in complete products and in products that use components of whey. This should help processors in adjusting to changes in consumption trends and in other aspects of the market.

Much of the economic incentive to use whey in food products will depend on the nonfat dried milk (NFDM) market. The higher the price of NFDM in relation to dried whey, the more pressure there will be to find ways to substitute whey products for NFDM. At the present time NFDM is 3 to 4 times the price of whey, and in many bakery processes whey and whey-blended products are a very satisfactory NFDM substitute.

TABLE 8.--Production of nonfat dried milk and dried whey in Wisconsin, 1960-1970[1/]

Year	Nonfat dried milk for human use (thousands of pounds)	Dried whey (thousands of pounds)
1960	424,938	87,495
1961	436,733	72,046
1962	510,206	94,595
1963	469,607	110,588
1964	468,158	136,433
1965	415,611	158,802
1966	272,470	207,789
1967	287,578	222,153
1968	253,538	240,577
1969	208,830	244,202
1970	186,677	292,981

[1/] Source: Wisconsin Agricultural Statistics, Wisconsin Statistical Reporting Service, various issues.

Forces outside the market that can influence whey utilization include the import and export policies of the United States and other dairy Nations, such as changes in quotas for cheese imported into this country, government subsidies for exporting dairy products, and the policies of foreign governments.

Increasing world demand for quality protein can lead to the development of new food products. Hopefully they can be exported to food-deficient areas and still be produced for a profit in this country.

The market for component parts and blends of whey and other products will continue to increase. While dried whey will still use a large part of total whey production, it will continue to be less profitable than selling other products. Competition for the dried whey market will continue to be tough. The firms that can develop and market unique and innovative products have the potential to make the most money.

Some industry leaders feel that a whey bias still exists. The image of whey is such that many people feel it is a disposal problem or "hog feed" rather than a food. Other people feel that the only bias against whey has been in the price, and that if the price is favorable, compared to alternative products, processors will not hesitate to use whey.

Greater cheese and whey production will mean that a market will have to be found for more whey cream. In 1970, the production of American cheese in Wisconsin was about 650 million pounds. Assuming a yield of 0.3 pound of fat removed from 100 pounds of whey, the butterfat from whey cream can be estimated at about 17 million pounds, or 21 million pounds butter equivalent. This is equal to more than 10 percent of the total butter produced in Wisconsin. Since whey cream also comes from other cheese whey, the above estimate is low.

SUMMARY

The marketing of whey has changed considerably in the last ten years. Most notable has been the greater use of whey in some form of processed product and the decline in the amount of whey that is just dumped or wasted.

Prices for dried whey have been remarkably stable for many years. Those products that use whey components as a part of other foods have been, and will continue to be, more profitable than dried whey. Competition will be keen as profitable markets are sought for the greater quantities of whey being produced.

Whey production will increase as cheese production increases. This will keep pressure on the industry to develop new uses, and to use existing methods of disposal and processing more efficiently.

Some Functional Properties of Whey Proteins

INTRODUCTION

Considerable effort is being expended by food processors to develop and perfect processes to fractionate the proteins of whey from the mineral and lactose components in order to produce an undenatured whey protein concentrate (WPC) suitable for use in a wide variety of food applications.

Commercial scale processes are being rapidly developed for preparing undenatured WPC in the following areas:

1. Electrodialysis for demineralizing whey by Ionics (11), Foremost (1), and Purity Products (2).

2. Ultrafiltration, especially by Abcor, Inc., (7) and Amundson's group at the University of Wisconsin (4). Others have used reverse osmosis but this has been primarily to concentrate the whey solids (13).

3. Metaphosphate complex has been developed by Wingerd and the Borden Company (16), and some additional work has been done by Pallansch's group at the U.S. Department of Agriculture in Washington (14) and by Swanson's group at the University of Wisconsin (6).

4. Sephadex gel filtration has been researched on a laboratory scale by Morr and co-workers (10) at the University of Minnesota using the basket centrifuge and large column (Sephamatic unit) and by Pallansch's group. Swanson and Ziemba (12, 3) originated the first large-scale attempt to fractionate whey by Sephadex, and the ENRG Division, Stauffer Chemical Co., Rochester, Minn., now processes up to one million pounds of whey per day by the Sephadex process.

Research is also proceeding to develop other processes for preparing whey protein concentrates. These include the carboxymethylcellulose (CMC) complex process by Hansen at Ohio State (5), the "ferripolyphosphate" complex process at USDA in Philadelphia (8), and the alcohol precipitation process (9).

The nutritional excellence of whey protein concentrates has been well established by Winston and others (18) and Wingerd (17). The protein efficiency ratio for whey protein concentrate is in the order of 3.1 compared to 2.5 for casein.

The need for undenatured whey protein concentrates for use in food formulations is twofold. First, the protein level in spray-dried whey solids is too low--only about 10 percent--and the high lactose and ash content limit the amount of protein that can be incorporated into a formulation. Secondly, WPC that has been prepared in the past by high-heat processes is gritty, insoluble, and totally lacking in functionality.

Now that we have substantial amounts of undenatured whey protein concentrates, prepared by any of the above described procedures, what can we do with them? Do they have any special or unique functional properties that would enable the food processor to buy and use them in his formulations? How do they compare with other protein concentrates, especially soy and egg proteins, for whipping, heat coagulation, emulsion capacity, solubility at different pH levels, etc.?

Perhaps most of these questions have already been answered, at least to the satisfaction of some. For example, advertisements and trade journal articles indicate that a number of food processing companies have spent considerable time and effort researching these questions and may already have the answers. However, the details of the procedures and results have not been published.

We have an ongoing research project at the University of Minnesota to investigate the functional properties of whey protein concentrates and to study different ways to alter and improve their functional properties. We have completed the initial phase of the project which was to survey the compositional and functional properties of approximately 20 different whey protein concentrates obtained from major commercial suppliers and from university and government researchers.

The procedures used in the study were more or less arbitrarily selected. No attempts were made to optimize the procedures or results. Therefore the data must be considered preliminary and no final conclusions should be drawn from them. More detailed studies, based upon these initial results, are now in progress in our laboratory. Results of these and similar studies are necessary before final conclusions can safely be made.

The composition of the different whey protein concentrates, grouped according to preparation process, is given in table 1. The ranges and mean values for protein, lactose, ash, and fat percentages are given on a dry basis. Mean protein contents varied from 32.9 percent (electrodialysis) to 66 percent (dialysis). Dialysis WPC was prepared in our laboratory by exhaustively dialyzing pH 4.6 whey against distilled water and freeze drying.

Mean lactose content varied from 0.8 percent (iron complex) to 51.8 percent (electrodialysis). Mean ash content varied from 2 percent (dialysis) to 54 percent (iron complex). The mean fat content varied from 0.6 percent (iron complex) to 7.3 percent (ultrafiltration). These data show wide compositional variation within a given WPC process and an even wider variation between the composition of whey protein concentrates prepared by different processes. The high lactose and ash-to-protein ratio in the starting whey makes it difficult to prepare a WPC with greater than 50 to 60 percent protein, even by exhaustive dialysis and protein complex precipitation processes.

TABLE 1.--Composition of whey protein concentrates

Preparation process	Number of samples	Protein	Lactose	Ash	NPN[1/]	Fat
		Percent				
Metaphosphate complex						
Range	3	54.1-58.0	12.7-13.2	10.6-15.5	1.1-1.3	3.3-7.2
Mean		55.7	13.0	13.7	1.2	5.3
Electrodialysis						
Range	5	27.3-37.0	40.5-60.0	1.4-19.7	5.4-7.7	2.4-4.3
Mean		32.9	51.8	9.0	6.7	3.3
Ultrafiltration						
Range	3	49.9-62.0	15.5-40.2	0.4- 6.2	2.7-6.8	1.4-14.7
Mean		56.5	27.2	3.4	4.8	7.3
Sephadex						
Range	2	38.7-45.1	-	-	-	-
Mean		41.9	24.9	11.5	4.9	0.8
Dialysis	1	66.0	26.2	2.0	1.5	2.0
CMC complex	1	49.8	20.1	8.0	-	1.2
Iron complex						
Range	2	32.7-37.4	0.7- 0.9	53.1-54.9	-	0.3-0.8
Mean		35.1	0.8	54.0	1.1	0.6

[1/] Nonprotein nitrogen expressed as percentage of total WPC N that was soluble in 12 percent TCA.

Table 2 contains elemental analysis data for the different whey protein concentrates. Although they are not shown here, the analysis included also Mg, Mb, Mn, and Bo. The metaphosphate and electrodialysis whey protein concentrates used in this part of the study were only the "acid" form; they were not neutralized with $Ca(OH)_2$, NaOH, or KOH. Thus, the analyses reflect their inherent composition prior to the addition of any other elements. These data were obtained on an emission spectrometer at the Soils Department, University of Minnesota. For some unexplainable reason, the emission spectrometer failed to read out correct P values for both the metaphosphate complex and the iron-metaphosphate complex whey protein concentrates. It is believed that the cause for this discrepancy may be the abnormally high metaphosphate level which interferes with the emission for phosphorus. Also, the iron level in the iron complex whey protein complex is low by a factor of about 100. Both electrodialysis and CMC complex whey protein concentrates contained high Na levels, which would be expected.

TABLE 2.--Elemental analysis of whey protein concentrates

Preparation process	Number of samples	P	K	Ca	Na	Fe	Al	Zn	Cu
		Percent				p.p.m.			
Metaphosphate complex	1	1/	1.05	-	0.30	-	34	14.1	47.9
Electrodialysis2/	2	1.03	2.20	0.69	3.22	-	144	16.0	16.0
Ultrafiltration	1	0.59	3.29	0.67	0.98	-	-	59.1	80.7
Sephadex	2	0.94	2.89	0.75	1.91	-	202	41.8	167.2
Dialysis	2	-	2.54	0.39	0.63	-	59	23.5	41.6
CMC complex2/	1	-	1.67	-	3.40	217	404	33.0	41.2
Iron complex2/	1	0.87 1/	1.97	0.49	0.58	1079 3/	94	48.9	123.0

1/Phosphorus content determined by the Sumner Colorimetric Procedure was 4.0 percent (metaphosphate complex) and 12.5 percent (iron complex).

2/Ash incompletely soluble in HCl/Licl solution.

3/Iron content by atomic absorption (8) was 9.0 percent.

Table 3 contains available lysine data obtained by the trinitrobenzenesulfonic acid (TNBS) procedure of Wartheson and others (15). The values are given as mg./100 mg. whey protein concentrate and mg./100 mg. protein. Available lysine varied from 4.5 to 11.5 mg./100 mg. protein. It is possible that heat treatment during condensing and drying steps of WPC preparation could account for these variations; however, it is believed that a major

TABLE 3.-- Available lysine content of whey protein concentrates

Preparation process	Number of samples	Available lysine content	
		mg./100 mg. WPC	mg./100 mg. protein
Metaphosphate complex	1	5.15	8.9
Electrodialysis			
Range	2	1.30-2.30	4.8-6.2
Mean		1.80	4.5
Ultrafiltration	1	4.45	7.9
Sephadex			
Range	2	2.85-3.60	7.4-8.0
Mean		3.22	7.7
Dialysis	1	4.50	6.8
CMC complex	1	4.80	9.6
Iron complex	1	4.30	11.5

cause is the interference of lactose with the available lysine test. Although special corrections were made to avoid this interference, it can be seen that the available lysine value for the different whey protein concentrates is roughly proportional to the lactose content. Electrodialysis WPC had the highest lactose content (51.8 percent) and the lowest available lysine. Iron complex whey protein concentrate had the lowest lactose content (0.8 percent) and also the highest available lysine content.

Initial pH and protein solubility as a function of pH are in table 4. Initial pH was determined by dispersing whey protein concentrate in distilled water (0.5 percent protein). Values ranged from pH 3.2 for acid metaphosphate complex to pH 8.3 for one ultrafiltration whey protein concentrate. The solubility data indicate that the metaphosphate complex, CMC complex, and iron-metaphosphate complex whey protein concentrates all had drastically reduced solubilities at pH 4 and below. An additional experiment was conducted to evaluate protein solubility as a function of pH (see figure 1). Most whey protein concentrates have a definite dip in their solubility curve between pH 4 and 5. This reduced solubility at the isoelectric region

TABLE 4.--Initial pH and solubility of whey protein concentrates[1/]

Preparation process	Number of samples	Initial pH	Protein solubility[2/]			
			pH 2	pH 4	pH 6	pH 8
			Percent			
Metaphosphate complex						
Range	3	3.2-6.9	4.1-48.8	6.2-55.2	65.0-87.1	68.9-96.5
Mean		5.5	31.1	24.0	73.1	85.9
Electrodialysis						
Range	5	5.0-7.2	83.5-94.2	88.1-95.6	87.2-95.6	87.2-100.1
Mean		6.6	90.4	92.2	91.1	93.6
Ultrafiltration						
Range	3	4.6-8.3	72.8-92.6	66.6-91.7	70.3-88.9	61.9-94.9
Mean		5.8	80.0	77.9	77.3	76.7
Sephadex						
Range	2	6.6-7.1	81.2-94.9	85.8-93.1	86.2-94.2	87.6-94.9
Mean		7.0	88.0	89.5	90.2	91.2
Dialysis	1	6.1	79.4	91.2	-	81.2
CMC complex	1	6.5	21.2	57.7	80.9	86.2
Iron complex						
Range	2	5.0-5.1	-	0.7-1.6	21.0-32.9	55.6-76.6
Mean		5.0	0	0.7	26.9	66.1

[1/]WPC dispersed in distilled water (0.5 percent protein concentration).

[2/]WPC dispersed in 100 ml. pH 2, 4, 6, or 8 buffer (1.0 percent protein concentration) at room temperature and stirred 30 min. The pH was readjusted and stirring continued 30 min. The solution was filtered through S & S 590 White Ribbon filter paper and examined for total N by micro-Kjeldahl.

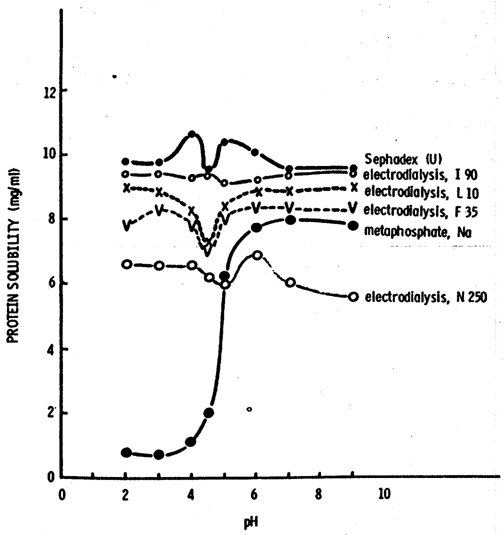

Figure 1.--Solubility of WPC dispersed in pH 6.98 phosphate buffer (1.0 percent protein concentration). Dispersion was stirred 2 hr., adjusted to pH from 2 to 9 with 1 N HCl or NaOH, and centrifuged at 1,000 x g. for 10 min. Supernatants were examined for total N by micro-Kjeldahl.

indicates partial denaturation of the whey proteins, since undenatured whey proteins are completely soluble at all pH values. The curve for metaphosphate WPC agrees with the data in the table, showing greatly reduced solubility at pH 4 and below.

Table 5 shows the solubility of metaphosphate complex and electrodialysis WPC at initial pH in water and after adjusting to pH 4.6 and centrifuging at 1,000 x g. The pH 4.6 solubility value cannot be used as an index of whey protein denaturation in metaphosphate complex WPC because of the precipitation effect by residual metaphosphate as the protein molecule reacquires a positive charge below its isoelectric point. However, the reduced pH 4.6 solubility value for electrodialysis whey protein concentrates confirms that from 12 to 40 percent of their proteins is apparently denatured.

TABLE 5.--Solubility and apparent denaturation of whey proteins in whey protein concentrate

Preparation process	Number of samples	Solubility at initial pH1/	Apparent denaturation2/
		percent	percent
Metaphosphate complex3/	1	57.3	90
Electrodialysis			
Range	5	83.1-98.1	12-40
Mean		92.4	22.4

1/WPC dispersed in distilled water (1.0 percent protein concentration), stirred 30 min. and allowed to stand overnight. Supernatant examined for total N by micro-Kjeldahl.

2/Supernatant from 1/ adjusted to pH 4.6 with 1 N HCl and centrifuged at 1,000 x g. for 20 min. to sediment insoluble (denatured) proteins. Final supernatant was examined for total N by micro-Kjeldahl and the percent depletion (apparent denaturation) calculated.

3/Sodium neutralized metaphosphate complex WPC.

Figure 2 shows polyacrylamide gel electrophoresis patterns that further confirm protein denaturation in whey protein concentrates compared to the proteins in the whey standard. Whey protein concentrates were adjusted to pH 4.6 and centrifuged at 1,000 x g. to sediment denatured proteins. Therefore, these patterns represent "undenatured" whey proteins. Definite changes have been produced in the electrophoretic patterns as a result of whey protein concentrate preparation. Recall that the pH 4.6 solubility approach is not reliable for determining protein denaturation in those whey protein concentrates containing residual metaphosphate. In all of these patterns it appears that alpha-lactalbumin is the protein component most susceptible to denaturation during WPC preparation.

The emulsion capacity of the different whey protein concentrates is shown in table 6. Emulsion capacity was determined as follows. Each WPC was dispersed in 100 ml. 1.0 M NaCl solution to obtain a 0.1 percent protein concentration. The dispersion was mixed rapidly in an Osterizer while corn oil was added at a uniform rate from a buret. The end point was read from a voltmeter when the emulsion was inverted and the electrical resistance increased rapidly to infinity. Values of all whey protein concentrates were similar, requiring between 34 and 42 g. corn oil for emulsion inversion, except CMC complex which had an emulsion capacity of 64 g. corn oil.

The whipping properties of the different whey protein concentrates are also listed in table 6. Whipping properties were compared by dispersing 10 g. WPC and 5 g. egg white solids in 100 ml. distilled water and whipping for varying periods of time necessary to obtain a meringue-like appearance. Mean percent overrun values ranged from 0 (metaphosphate WPC which failed to form a stable foam) to 760 percent for dialysis WPC. CMC complex formed a thick paste and therefore it had to be diluted with an extra 100 ml. of water. None of the whey protein concentrates produced as high an overrun as was obtained for sodium caseinate of 1,120 percent. Egg white solids produced an overrun of 900 percent.

Next, WPC was used as protein source in a whipped topping mix. The composition of the whipped topping mix and the procedure for preparing it are as follows:

Composition

	Percent
Cream, 35 percent	15
Frodex 24	10
Sucrose	7
NFDM or WPC	3
Water	64
Dariloid KB	0.35
Carageenin	0.05
Tween 65	0.18
Tween 60	0.10
PGM P-06	0.20

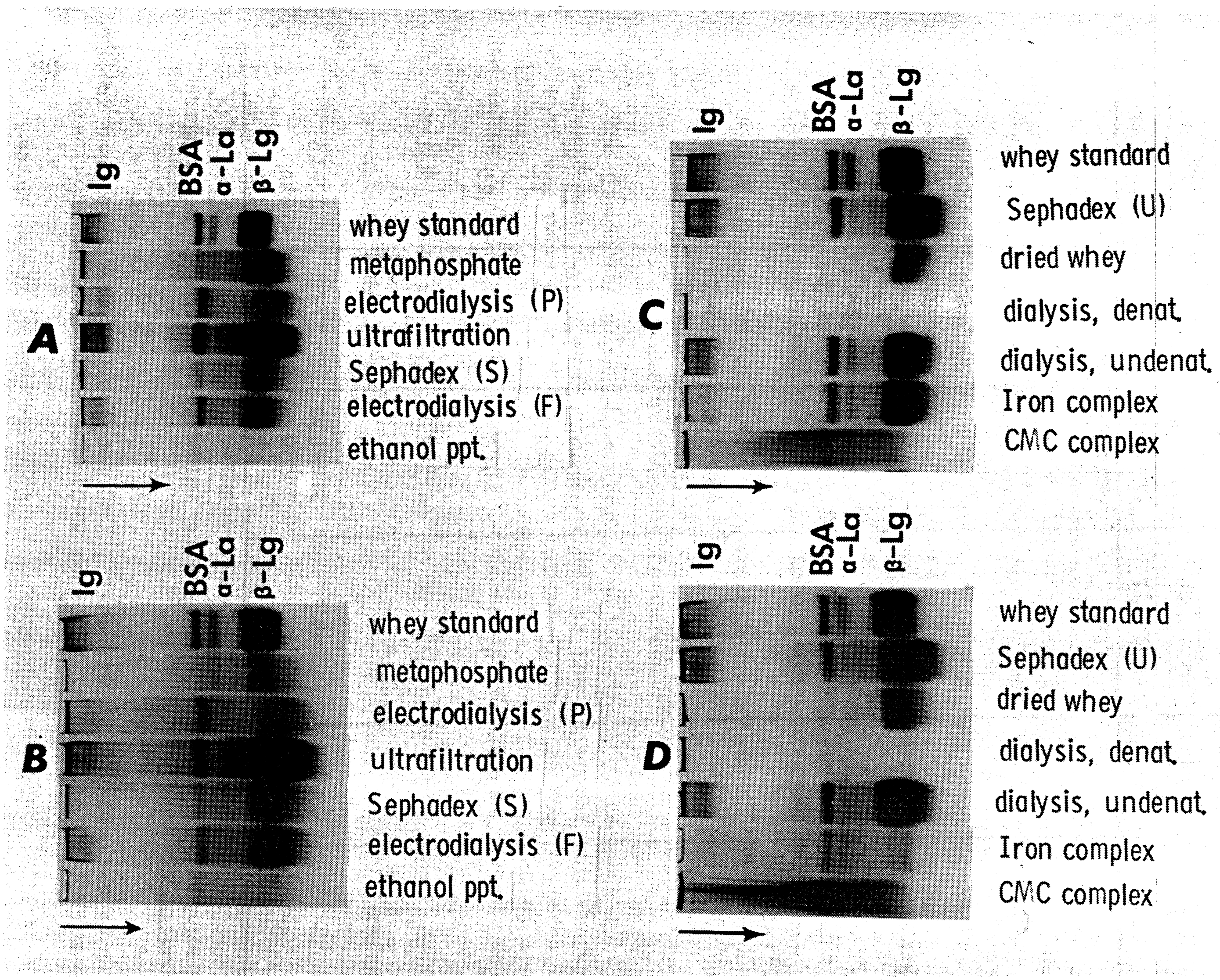

Figure 2.--Polyacrylamide gel electrophoresis (PAGE) patterns of WPC dispersed in pH 6.98 phosphate buffer (1.0 percent protein). Dispersions were stirred overnight at 0-5° C., dialyzed 48 hr. against 2 changes of fresh buffer and centrifuged at 1,000 x g. The supernatant (soluble proteins) was examined by PAGE - patterns A and C. The supernatants were adjusted to pH 4.6 and centrifuged at 1,000 x g. Final supernatants (undenatured proteins) were examined by PAGE - patterns B and D. Dialysis, denatured WPC, was heated at 90° C. for 30 min. to denature the proteins. Dried whey was a commercial source of spray-dried whey solids.

TABLE 6.--Emulsification and whipping properties of whey protein concentrates

Preparation process	Number of samples	Emulsion capacity[1]	Whipping properties		
			Overrun	Time	Drainage
		grams	percent	minutes	ml.
Metaphosphate complex					
Range	3	32-40	-	-	-
Mean		37	0	0	0
Electrodialysis					
Range	5	39-42	0-1020	2-11	9-35
Mean		41	632	4.5	17.5
Ultrafiltration					
Range	3	36-49	460-900	0.5-15	10-36
Mean		40	453	7.8	23
Sephadex					
Range	2	-	600-760	3.5-10	13-30
Mean		42	680	6.8	22
Dialysis	1	41	760	10	25
CMC complex	1	64	400[2]	2	0
Iron complex					
Range	2	26-41	520-600	-	12-16
Mean		34	560	3	14

1/ Grams corn oil required to produce infinite electrical resistance in the emulsion.

2/ Due to extremely high viscosity, CMC complex WPC was dispersed in twice as much (200 ml.) water as other WPC.

PROCEDURE

1. Blend dry ingredients and mix into water plus cream.
2. Heat mix to 150° F. (65° C.) and blend in melted emulsifiers.
3. Pasteurize at 170° F. (76.5° C.) for 5 minutes.
4. Homogenize at 1600 plus 800 p.s.i.
5. Cool to 40° F. (5° C.) and age 24 hours prior to whipping.
6. Whip 2 minutes at full speed in a Hamilton-Beach mixer at room temperature.
7. $\text{Overrun} = \dfrac{\text{weight liquid} - \text{weight whip}}{\text{weight whip}} \times 100$
8. Viscosity determined by Brookfield HBT viscometer using a 4.8-cm. T-bar spindle at 50 r.p.m. immediately after whipping.
9. Drainage for 24 hours through a wire screen

$$D = \frac{\text{weight of drained topping}}{\text{weight of topping to screen}} \times 100$$

The formulation contains about 5 percent fat, 27 percent solids, and 3 percent nonfat dry milk (NFDM) or WPC as the major protein source. No attempt was made to equalize final protein levels in the different mixes, although they were generally the same. The whipping properties are given in table 7. The whipped topping that contained NFDM as protein source

TABLE 7.--Whipping properties of whipped topping mix containing whey protein concentrate or nonfat dry milk solids for protein source[1/]

Protein source	Number of samples	Whipping properties		
		Overrun	viscosity	Drainage
		percent	(cp)	percent
Nonfat dry milk solids	1	219	18	6.4
Electrodialysis WPC				
Range	3	150-175	8-13	11-51
Mean		158	10	37.8

[1/] See Materials and Methods section for details on composition, preparation, and whipping procedure used.

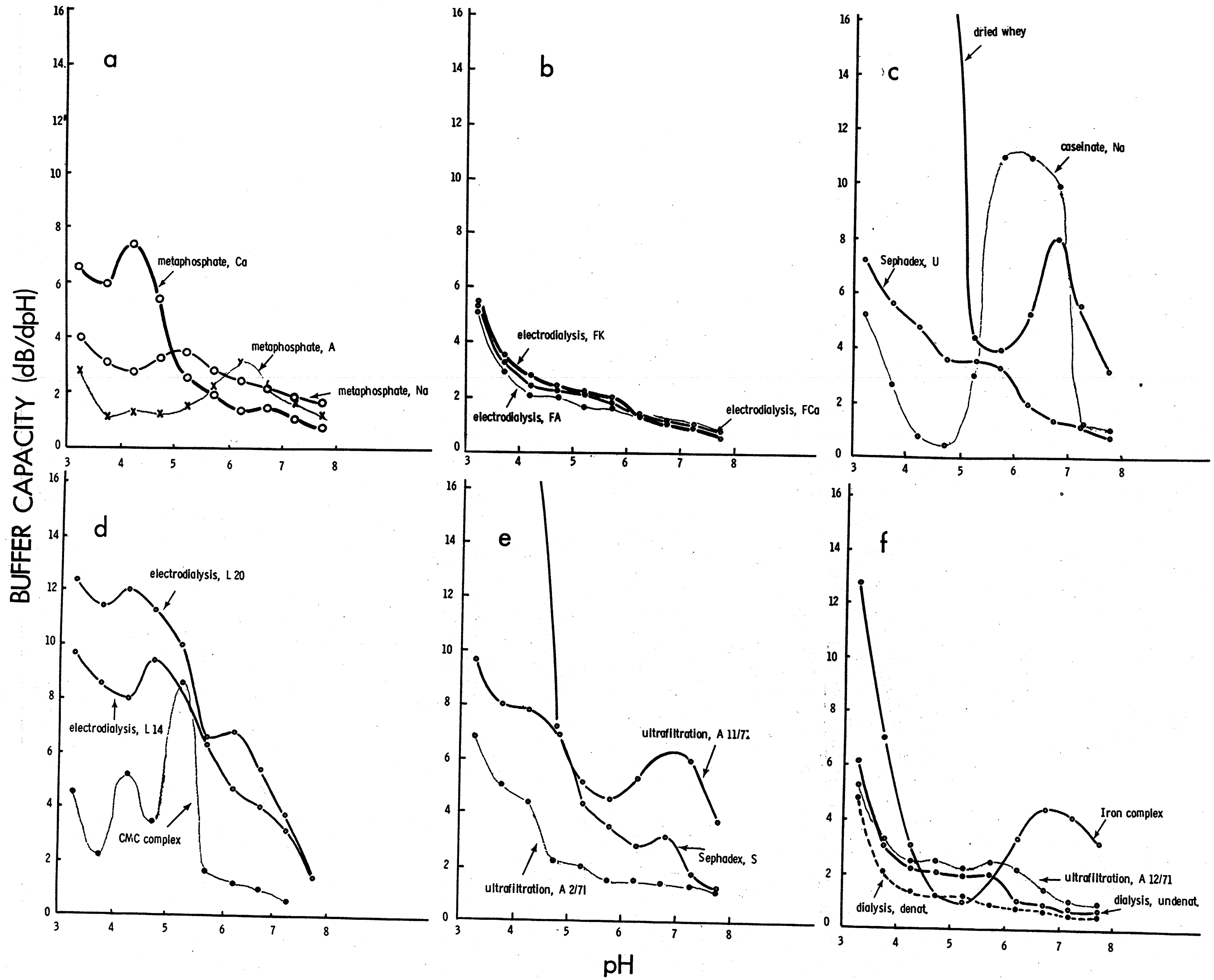

Figure 3.--Buffer capacities of whey protein concentrates dispersed in distilled water (0.5 percent protein) and titrate with 0.1 N HCl or NaOH.

produced an overrun of 219 percent. Three mixes containing electrodialysis WPC produced from 152 to 175 percent overrun. The foams from the NFDM mix were more viscous and stable than those made with WPC. From these limited data, casein appears superior to WPC for formulating whipped topping mixes.

The final segment of the study was to determine pH buffer capacities of WPC. The procedure used is as follows. WPC and other protein source materials were dispersed in distilled water at an 0.5 percent protein concentration and titrated to pH 3 with standard acid or to pH 8 with standard alkali using a recording titrator. Buffer capacity was calculated by the equation shown for each 0.5 pH change.

$$\frac{d\ B}{d\ pH} = \frac{\text{Milliequivalents titrant}}{\text{Grams protein} \times \Delta\ pH}$$

The buffer capacity of each WPC (shown in figure 3) is strongly influenced by the degree of demineralization and the presence of residual protein precipitant polyions such as the metaphosphates and CMC. Dried whey (figure 3c) had the highest buffer capacity below pH 5.5 which was due to the high levels of phosphates, citrates, and other milk salts. Electrodialysis, dialysis, and Sephadex WPC produced generally lowest buffer capacity curves throughout the entire pH range. Such low buffer capacities would be of interest for those using WPC in formulating, for example, an acid pH carbonated beverage.

In conclusion, wide differences exist in the composition of WPC. These differences reflect variations in the process of preparation and appear to affect certain functional properties of the WPC. Significant amounts of whey protein denaturation were observed for a number of the concentrates, even for those prepared by the mildest conditions possible such as dialysis and freeze drying. This suggests that drying alone or storage of the dry product may result in whey protein denaturation.

Whipping properties and emulsion capacity of WPC were only fair under the experimental conditions used.

Buffer capacities were lower for whey protein concentrates than for spray-dried whey solids. The lower buffer capacity curves were produced for those whey protein concentrates that were most completely demineralized and contained minimal polyion protein precipitants.

These results represent merely a beginning, a jumping off place. Much research is required to completely characterize whey protein concentrates and to evaluate their functionality in these and the other food applications.

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Use of Whey in Baking

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About 18 percent of the production of nonfat dry milk (NDM) in the United States is currently used by the bakery trade. In 1971 this amounted to 175 million pounds. Of late, support prices of NDM have increased above 32 cents per pound. As an economy for bakery usage, blends of NDM and whey are replacing some of the NDM previously used. It is therefore to our advantage to know something further of the properties of wheys in baked goods. Today I want to discuss some of the baking properties of sweet and cottage cheese wheys in sponge breads with a few comments on why they behave as they do and what we might do to upgrade their performance.

EFFECTS ON DOUGH ABSORPTION AND MIXING TIME

Table 1 shows the farinograph absorption[1/] of doughs made from both hard red spring (HRS) and hard red winter (HRW) flours containing salt and dried whey that was heat-treated in the fluid state. The table shows that cottage cheese whey actually lowers absorption of the doughs about 2 percent. Sweet wheys may lower them slightly. The addition of lactic acid to sweet whey (equivalent to 3.8 percent of the powder) decreases absorption of sweet whey doughs to that of the doughs with cottage cheese whey. Although not shown here, addition of lactic acid to sweet whey also extends the farinograph stability of this dough, similar to that of a dough containing cottage cheese whey.

Table 2 shows the farinograph absorption and other characteristics of

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[1/] A farinograph measures the resistance of a flour to mixing as water is added. The farinograph absorption is the percentage of water added at the point where optimum consistency is achieved, and is a measure of dough strength.

TABLE 1.--Farinograph absorption of doughs containing 2 percent NaCl as affected by adding heat-treated and dried wheys

Type of whey used	Hard red spring flour		Hard red winter flour	
	Whey added (percent)	Farinograph absorption (percent)	Whey added (percent)	Farinograph absorption (percent)
Control	0	57.7	0	59.7
Cottage cheese whey	4.2	55.3	4.6	57.7
Commercial sweet whey	4.2	56.3	-	-
Laboratory-prepared sweet whey (LSW)	-	-	4.2	59.3
LSW + 0.16 percent lactic acid	-	-	4.2	57.0

TABLE 2.--Effect on farinograph characteristics of replacing with acid whey some of the nonfat milk added to hard red winter wheat flour

Nonfat dry milk	Acid whey	Salt	Farinograph characteristics			
(percent added)			Absorption[1/] (percent)	Arrival time (minutes)	Peak time (minutes)	Stability (minutes)
6	0	2	64	10.5	20	23.5
4	2	2	61	8.0	21	35.0

[1/] Total dough weight held at 480 grams.

HRW flour doughs containing 2 percent salt and either 6 percent NDM or a mixture of 4 percent NDM and 2 percent cottage cheese whey. Replacement of milk solids with cottage cheese whey drops the absorption from 64 to 61 percent. It reduces somewhat the time required for optimum dough development to be achieved on the farinograph (arrival time), has little effect on the time required to reach peak development, but greatly increases the overall stability of the dough to mixing.

Table 3 shows the results of baking these doughs into bread. The best loaf volume and total score for the control bread containing only NDM is at 64.5 percent absorption, while that containing cottage cheese whey produces the best bread at 61 percent absorption, the same absorption indicated as optimum on the farinograph. The data show that increasing the water absorption progressively decreases the volume of the loaf containing dried acid whey. An average of three different mixing times was used at each absorption.

TABLE 3.--Effect of varying water absorption and mixing time on the baking quality of hard red winter flour containing nonfat dry milk only and nonfat dry milk plus acid whey

Variable	6 Percent NDM added		4 Percent NDM, 2 percent acid whey added	
	Loaf volume (c.c./100 g.)	Total score	Loaf volume (c.c./100 g.)	Total score
Water absorption				
61 percent	2652	87.4	2656	89.5
64.5 percent	2720	89.5	2608	88.7
68 percent	2629	88.5	2582	88.8
Mixing time				
4 minutes	2675	89.2	2462	89.6
6 minutes	2685	88.6	2675	90.0
8 minutes	2640	87.5	2709	89.3

As was shown in table 2, cottage cheese whey increased the farinograph stability of the dough to mixing from 23.5 to 35 minutes. Table 3 gives baking data showing that cottage cheese whey extends the mixing requirements of these HRW doughs. The control dough containing 6 percent NDM produces optimum bread at 4 to 6 minutes' mixing, while that containing cottage cheese whey requires 6 to 8 minutes' mixing to produce optimum bread.

Table 4 compares the loaf volumes and bread scores of HRS flour doughs containing 4.3 percent dried cottage cheese whey with those without whey or milk solids. The loaf volumes and bread scores of those with whey are progressively increased with mixing, while the loaf volumes and bread scores of the controls are optimum at 3-1/2 or 6 minutes' mixing.

TABLE 4.--Effect of adding 4.3 percent cottage cheese (acid) whey on the mixing time of HRS flour doughs

Mixing time (minutes)	Loaf volume (c.c./100 g.)		Bread score	
	Without whey	With whey	Without whey	With whey
3-1/2	639	515	60.0	61.1
6	625	542	61.0	61.6
8-1/2	642	559	59.0	62.1

EFFECT OF HEAT PROCESSING OF COTTAGE CHEESE WHEY ON BREAD QUALITY

It is known that if fluid milk is to be used in bread formulas, it must be heat-treated for optimum dough handling and baking performance. Table 5 shows the effect of heat-treating cottage cheese whey on the baking characteristics of flours to which the whey is added. Two degrees of treatment were used--low heat, after which 11.5 milligrams of undenatured protein nitrogen per gram remained in the whey, and high heat, which reduced the undenatured protein nitrogen in the whey to 2.2 milligrams per gram. Both heat treatments of the whey increased the proof time somewhat and depressed the loaf volume significantly, but slightly improved the bread and grain scores. There was not much difference between the effects of the high and low heat treatments on the baking characteristics of the dough, except that the high heat did not depress the loaf volume as much as the low heat.

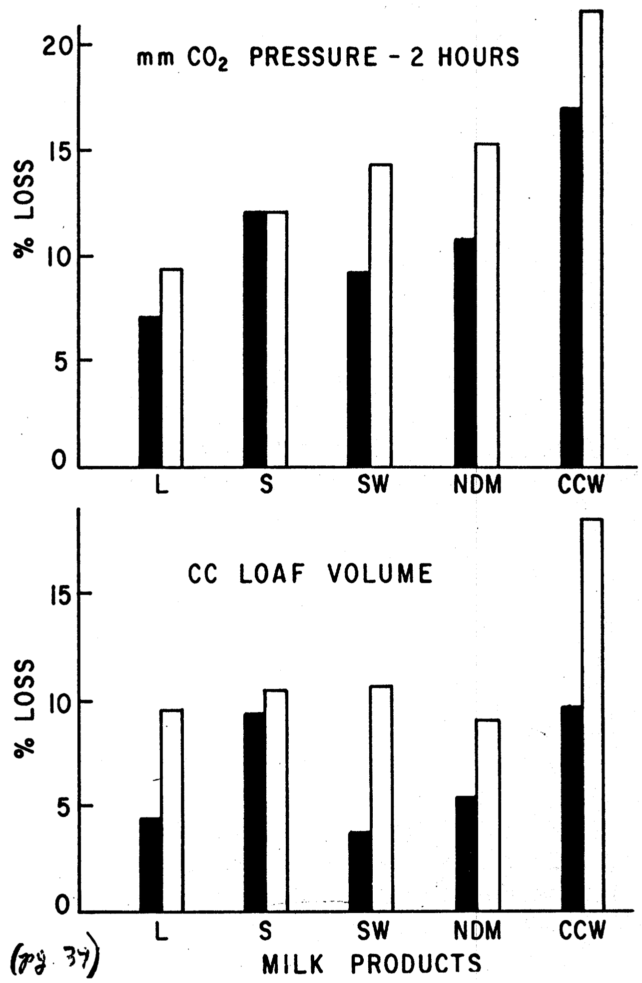
TABLE 5.--Effect of heat-treating cottage cheese (acid) whey on the baking characteristics of flour to which the whey is added at the 4.3 percent level

Treatment of acid whey	Proof time (min. to 5/8 in.)	Loaf volume (c.c./100 g.)	Bread score	Grain score
None	64	704	63.6	17.2
Low heat 1/	71	631	64.1	18.1
High heat 2/	72	674	64.0	18.1

1/ Whey protein nitrogen 11.5 mg./g.

2/ Whey protein nitrogen 2.2 mg./g.

Figure 1 shows that the carbon dioxide production of doughs containing various types of dried milk byproducts is related to the changes in loaf volume of the resulting bread. Both dry and compressed (wet) yeasts were used. The data imply that the lactose in wheys and NDM contributes significantly in depressing both CO_2 production of the doughs and loaf volumes of the bread. The figure also shows that the loss in CO_2 production and loaf volume can be reduced in most cases if dry yeast is used instead of compressed yeast. Since dry yeast is more tolerant to higher levels of sugar, this observation is plausible.



(pg 37)

Figure 1.--Losses in carbon dioxide production and loaf volume produced by sugars and dairy byproducts added to HRW flour doughs proofed 60 min. and baked with dry yeast (black bars) and compressed (wet) yeast (white bars). Sugars added, 3 percent; dairy byproducts, 3 percent lactose (flour basis). L=lactose, S=sucrose, SW=sweet whey, NDM=nonfat dry milk, CCW=cottage cheese whey.

EFFECT OF WHEY PROTEIN CONCENTRATES ON BAKING QUALITY

If lactose itself is a big factor in the volume-depressing effects of wheys, its removal in whole or in part should leave a whey protein concentrate (WPC) with improved baking quality. This we have shown under some circumstances. Since it has been estimated that 37 percent of bakers use

EFFECT OF LACTOSE ON BREAD VOLUME

Why does whey depress loaf volumes even when it is properly heat treated? Since high-heat-treated NDM also depresses sponge loaf volumes, we suspected that the lactose in both whey and NDM may be a factor in this reaction. Experiments were conducted in which 3 percent lactose, 3 percent extra sucrose, and milk products at such a level to contribute 3 percent added lactose, were added to HRW flour doughs. Some of the results are shown in table 6. Using 7.5 percent, or a normal level of sugar in the sponge and dough formula, addition of lactose increases proof time. Wheys and NDM may increase it still further. Extra sucrose also increases proof time. If the doughs are all proofed for 60 minutes (a constant proof time), lactose, extra sucrose, sweet whey and NDM depress volumes to about the same extent (from 9 to 12.7 percent). Cottage cheese whey decreases volumes the most (by 17.5 percent) due in part to its acid content. Proofing to height and reducing the formula sucrose base to 4.5 percent both minimize the volume changes caused by these additives. The results suggest that the lactose or other added sugar functions by inhibiting yeast action. To test this supposition we carried out other experiments.

TABLE 6.--Effect of added sugars on loaf volume of HRW flour doughs proofed to height and for time

Additive	Time to proof to height (min.)	Reduction in loaf volume (pct.)		
		Proofed to height[1]	Proofed for time (60 min.)	
	Sucrose base: 7.5 pct.	Sucrose base: 7.5 pct.	Sucrose base: 7.5 pct.	Sucrose base: 4.5 pct.
None	56	--	--	--
3 Percent lactose	60	+0.5	9.5	3.4
3 Percent extra sucrose	64	3.2	10.2	8.2
4.2 Percent sweet whey	65	+0.3	12.7	6.9
4.6 Percent cottage cheese whey	66	5.5	17.5	14.7
6 Percent nonfat dry milk	65	3.2	9.0	4.3
4.2 Percent sweet whey +0.16 percent lactic acid	68	8.4	--	--

[1] 5/8 in. above the top of the pan.

milk products for their nutritional value, this purpose could be achieved just as effectively (and perhaps even more so) by adding WPC from which much of the lactose has been removed. Table 7 shows the effect on loaf volume of adding, at the 2 percent protein level (flour basis), WPC of reduced lactose contents and with various percentages of denatured protein.

TABLE 7.--Effect on loaf volume of adding cottage cheese whey protein concentrates to flour at 2 percent protein level

Whey protein concentrate[1]	Lactose added (percent)	Protein denatured[2] (percent)	Change in loaf volume (percent)
UFG 70	0.55	13.5	-6.9
POLYG 78 (1)	0.075	38	0
POLYG 78 (2)	0.027	30	-1.5
UFG 83	0.15	62	0

[1] UFG = Ultrafiltration and gel permeation; POLYG = Polyphosphate precipitation and gel permeation; numbers following designation indicate approximate percentage of protein in the preparation.

[2] Measured as protein insoluble at pH 5.1.

Table 7 shows that whey protein concentrates which have both a relatively low level of lactose and a sizable percentage of their protein denatured (as POLYG 78 and UFG 83) cause very little change in loaf volume. UFG 70, which has only 13.5 percent of its protein denatured and contains 18.9 percent lactose (contributing only 0.55 percent on a flour basis) lowers loaf volume to some extent, presumably because of its low level of denatured protein. These preparations also contribute to crust coloration, but less than that of NDM. With the flour used, the inclusion of WPC gave crust coloration that was more than adequate.

Table 8 shows that if WPC preparation UFG 83 is used along with Emplex emulsifier, it should be possible to fortify the flours with perhaps as much as 6 percent protein and still maintain a good quality of bread. In these experiments the loaf volume, bread score, and keeping qualities of bread made from flour containing 5 percent of this WPC and the emulsifier compared most favorably with bread containing no emulsifier or milk solids which was used as a control. Going to 7 percent protein began to depress the loaf volume.

TABLE 8.--Effect of 0.5 percent Emplex emulsifier on the baking quality of sponge bread made from HRS flour fortified with whey protein concentrate

Baking characteristic	Whey protein concentrate (66 percent absorption)	
	5 Percent UFG 83	7 Percent UFG 83
Change in loaf volume from control[1/] (percent)		
Without Emplex	-5.3	-13.4
With Emplex	0.0	- 6.2
Change in bread score from control[1/] (percent)		
Without Emplex	-1.7	+ 0.5
With Emplex	0.0	+ 1.3
Keeping quality of bread (grams to depress slice 3 mm. after 3 days)[2/]		
Without Emplex	--	19.5
With Emplex	10.7	12.3

[1/] Control: No milk solids, no Emplex, 60 percent absorption.
[2/] Value for control: 14.3 g.

Figure 2 shows that the farinograph absorption of flours containing WPC is increased proportionately with the percentage of denaturation of the total protein (measured as protein insoluble at pH 5.1). Thus, the farinograph absorption of flour enriched with whey protein can easily be raised as much as 4 percentage points if, instead of essentially undenatured protein, a WPC such as UFG 83 is used whose protein denaturation is around 60 percent.

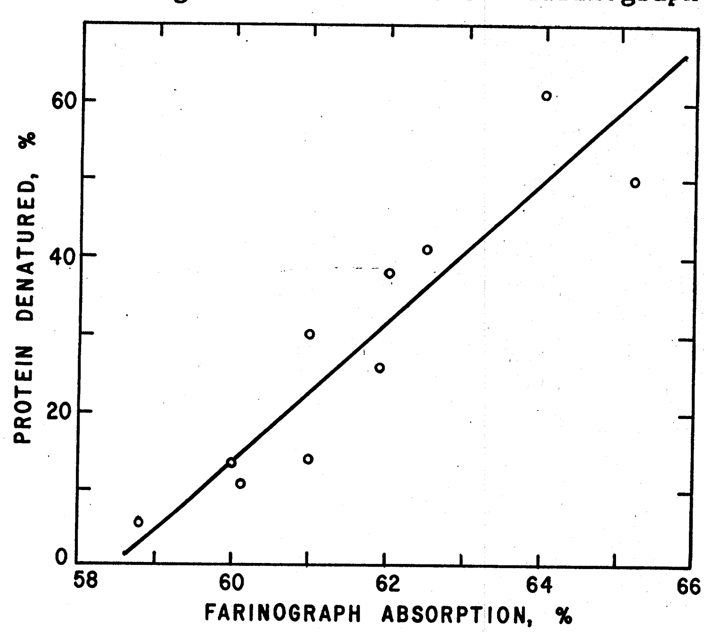


Figure 2.--Farinograph absorption of HRS flour fortified with 2 percent whey protein concentrates as affected by protein denaturation of the concentrates.

CONCLUSION

In conclusion, we find that wheys, even if high-heat-treated, tend to decrease bread-baking quality by increasing dough mixing time, by lowering water absorption, and by depressing bread volume. Removal of their lactose in whole or part by suitable techniques yields a high protein concentrate which can be dried. If suitably denatured, this preparation can yield doughs of increased water absorption and unchanged mix requirements, and will cause little to no change in bread volume. This holds at a protein/flour level equivalent to that given by the addition of 6 percent NDM. Moreover, addition of Emplex emulsifier permits the addition of even higher levels of protein. We feel whey protein concentrates offer a means to upgrade the protein quality of breads, and at the same time cause little or no loss in the functional qualities of doughs and breads.

DISCUSSION

QUESTION: What test did you use to measure percent denaturation of whey protein and what was your control?

MR. GUY: We add acetic acid and sodium acetate and come up with a pH of 5.0 to 5.1. We measure the total protein in solution, subtracting out for nonprotein nitrogen. Then we centrifuge the suspension and determine the protein in the supernatant. The difference between the two determinations represents denatured protein. So it's an insolubilization of the protein at pH 5.1. Interestingly enough, this is the pH of the dough in fermented media.

The Use of Cheese Whey in Beverages

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The use of cheese whey as a base for the manufacture of beverages, both alcoholic and nonalcoholic, has been attempted in Europe for many years. As early as the 17th century, medicinal properties were ascribed to whey which led to the establishment of "whey houses" designed for the treatment of a variety of human ailments. Whey was regarded as a particularly valuable aid to the digestion.

Because of the tremendous increase in recent years in the quantity of cheese whey produced, particularly in the United States, and the resultant environmental pollution arising from wastage of this valuable nutrient source, new uses must be found for whey or whey fractions. Consequently, renewed research efforts directed toward producing whey-based beverages have been initiated.

Some success has been achieved in developing beverages containing whey constituents. These are shown in table 1. The most successful of these products is Rivella, a sparkling, crystal clear infusion of herbs in deproteinized whey that was brought onto the market in Switzerland in 1952. Since then, it has become firmly established in the soft drink market in Switzerland and is now being sold in most of Western Europe, being promoted as something of a therapeutic tonic. All the products listed here are sparkling and have been deproteinized, with the exception of Tai, which is a conventional soft drink fortified with a whey protein concentrate to contain 1.5 percent protein. Since the whey protein concentrate used contains lactose and whey salts, these also are found in the beverage. Note should be taken of the fact that none of these beverages are currently available in the United States.

A literature search indicates that research directed toward use of whey in beverage manufacture is most active in Europe. There, it generally has been directed toward the production of sparkling deproteinized fermented whey-based beverages. However, recent research efforts, particularly in the United States, have been directed toward utilizing whole whey in the form of

TABLE 1.--Commercially produced carbonated beverages from whey

Brand	Year marketed	Country of origin	Type
Rivella	1952	Switzerland	Nonalcoholic Herbs
Whey champagne	1966	Poland	Alcoholic Wine-like
Whey kwas	1966	Poland	Alcoholic Kefir-like
Bodrost	1969	Russia	Alcoholic Beer-like
Tai	1971	Brazil	Nonalcoholic Citrus

nutritious whey beverages, both carbonated and noncarbonated. Table 2 outlines the types of beverages formulated for which high consumer acceptability is claimed. The citrus flavored beverages, particularly orange, have the highest acceptability. Protein content is lowest in those beverages designed for the snack trade. Only the liquid breakfast formulations have protein contents approaching that of milk. All of the beverages shown in the table employ cheese whey in the unfractionated form; none of them can be considered to resemble even remotely the carbonated soft drinks that dominate the American beverage market.

TABLE 2.--Recent research toward production of nutritious whey beverages

Beverage use	Formulation			Protein (percent)
Snack beverage	Acid whey powder or fluid acid or sweet whey	+	Fruit juice or fruit juice concentrate (orange)	0.5-1.0
Imitation milk	Fluid acid or sweet whey	+	Vegetable hydro-colloids + vegetable oils	1.0-1.5
Liquid breakfast	Fluid acid or sweet whey	+	Soybean powder + Citrus flavoring	2.5-3.5

The products of the soft-drink industry in the United States have become ubiquitous to the point where their containers alone are considered to be environmental pollutants. Since these beverages consist primarily of sugar, water, flavoring, and CO_2, many nutritionists consider them to be a dietary pollutant. Although soft drinks contribute only about 4.3 percent of the caloric requirement of the population of the United States, their appeal to young people is strong. Diets drifting toward a combination of chips, dips, and carbonated beverages cannot be considered well balanced. However, changing dietary habits is difficult and one obvious step toward better nutrition would be to fortify soft drinks with valuable nutrients without detectable change in flavor or appearance.

The possible magnitude of a fortification program of this type can be drawn from the fact that in 1970, 74,319,240,000 8-ounce bottles of soft drinks--or 362.8 bottles per capita--were consumed in the United States. They had an estimated value of $4,799,000,000. It can be easily seen that this is a high volume, big money operation.

The amount of recoverable protein in cottage cheese whey wasted annually in the United States is estimated at 43,124,000 pounds. If this protein is worth $1.50 a pound, as the more optimistic researchers believe, it represents $64,686,600, a sizeable potential income for protein processors.

When considering the volume of soft drinks manufactured in the United States, the potential amount of acid whey protein available and its projected price, it is easy to calculate that about 12 percent of the total soft drink production in the United States could be fortified to contain 1 percent protein at an added materials cost of about 3/4 of a cent per 8-ounce bottle. This does not seem to be unreasonable. Therefore, we carried on research to determine if proteins isolated from cottage cheese whey, regardless of expense, had functional properties that made them suitable for soft drink manufacture. Fortification with whey proteins alone represents a different approach than that taken by previous researchers. The development of new methods to isolate the whey proteins from the lactose and salts make this approach possible.

Figure 1 schematically presents the method routinely used by us in isolating undenatured proteins from cottage cheese whey. It can be seen that ultrafiltration and gel permeation are employed in sequential fashion to remove lactose and salts from the whey protein. The resulting protein solution is condensed and dried using conventional techniques. You will note that centrifugal clarifiers are used to remove insoluble material formed during the purification steps. The amount of protein loss entailed by use of this procedure is relatively high but the quality of the end product is excellent. Typical compositional data are shown at the bottom of the diagram.

This whey protein concentrate was added to carbonated soft drinks using recipes shown in table 3. Since most of our experience is with dairy product manufacture, we used recipes and materials drawn from the soft drink industry. Solid CO_2 was used to achieve carbonation.

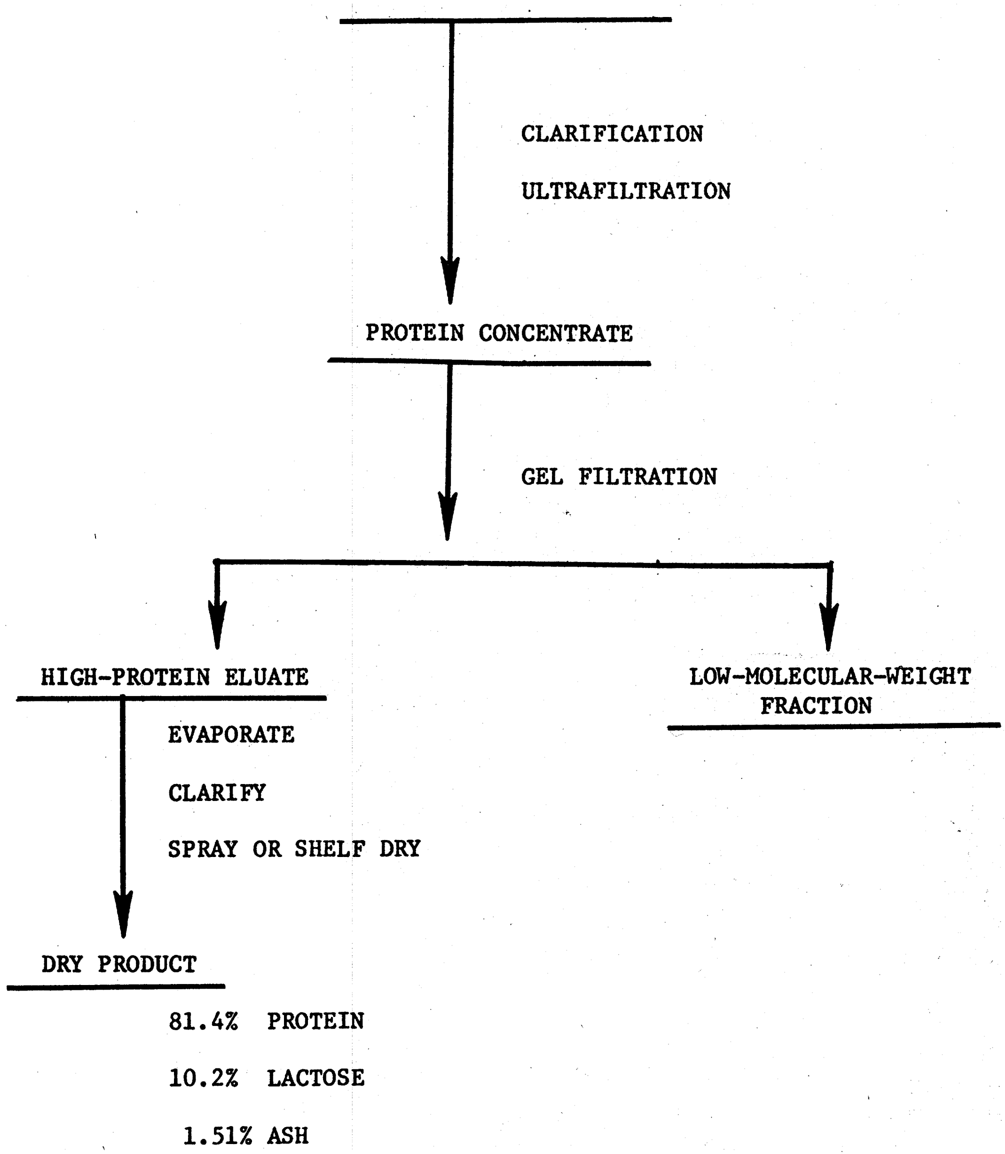

Figure 1.--Isolation of undenatured cottage-cheese whey proteins from lactose and salts by Dairy Products Laboratory method.

The carbonated beverages fortified with 1 percent whey protein maintained excellent clarity and color during one year of storage on laboratory shelves and in glass-fronted laboratory cabinets. In comparison to a freshly made control, the lime flavor underwent a slight color shift--actually a fading--at the end of the year. It also had a slight stale whey taste, but this was not particularly objectionable. At the end of 200 days no whey taste was detectable, but there was a slight color change.

Carefully prepared spray-dried whey protein concentrates can also be used to fortify the powders that are dissolved in water to produce the highly popular "ade"-type beverages. Seven flavors of these beverage powders were fortified with 0.5 percent and 1.0 percent protein by weight and compared to an unfortified control. The ratings given to the beverages on the basis of the conventional 10-point hedonic scale by a panel of experienced dairy-product judges are shown in table 4. Most of the protein-added drinks, especially

TABLE 3.--Composition of protein-fortified carbonated soft drinks (percent by weight)

Ingredient	Flavor			
	Strawberry	Orange	Lemon	Lime
Sucrose	12.0	14.0	13.0	13.0
Flavoring	0.37	0.37	0.37	0.37
Citric acid	0.37	0.185	0.74	0.74
Protein	1.0	1.0	1.0	1.0
Water	86.26	84.44	84.89	84.89
Carbon dioxide volumes	2	1	1	1
pH before carbonation	2.50	2.66	2.35	2.46

TABLE 4.--Organoleptic evaluation of protein fortified non-carbonated "ade" drinks

Flavor	Control	0.5% Protein	1.0% Protein
Cherry	7.0	6.5	5.5
Grape	7.2	6.8	6.3
Tart lemon	5.7	5.2	5.5
Lemon-lime	7.2	6.5	6.2
Orange	6.2	5.9	6.0
Raspberry	6.3	6.7	6.4
Strawberry	6.5	5.9	6.0

at the 0.5 percent level, received flavor scores not significantly lower than the controls and one (the raspberry) actually was rated higher. In general, the judges detected the presence of the whey, even at the 0.5 percent level, except for some of the citrus-flavored drinks. The whey caused a slight color shift in all the beverages, this being most pronounced in the lemon-lime, which became less green and more yellow.

None of the scores were low enough to register dislike, although at the 1.0 percent concentration some scores approached an indifferent response. Since the higher protein level resulted in a lower flavor score in most cases, it may be difficult to produce acceptable soft drinks containing as much protein as milk.

While empirical studies of this type bring us into the "ball park" of soft drink fortification, more fundamental data are needed to make commercialization feasible. Virtually no information is published related to the solubility and stability of mixed whey proteins at the low pH's that characterize most carbonated soft drinks. Figures 2 to 6 will present data acquired in our studies of the whey protein concentrates we made as described previously.

Figure 2 shows how the solubility of our whey protein concentrate changes with the pH of the solution. Also shown is the change in turbidity of the solution over the same pH range. As expected, the drop in solubility is accompanied by an increase in turbidity in the region of the proteins' isoelectric points. Somewhat unexpected was the clearing of the protein

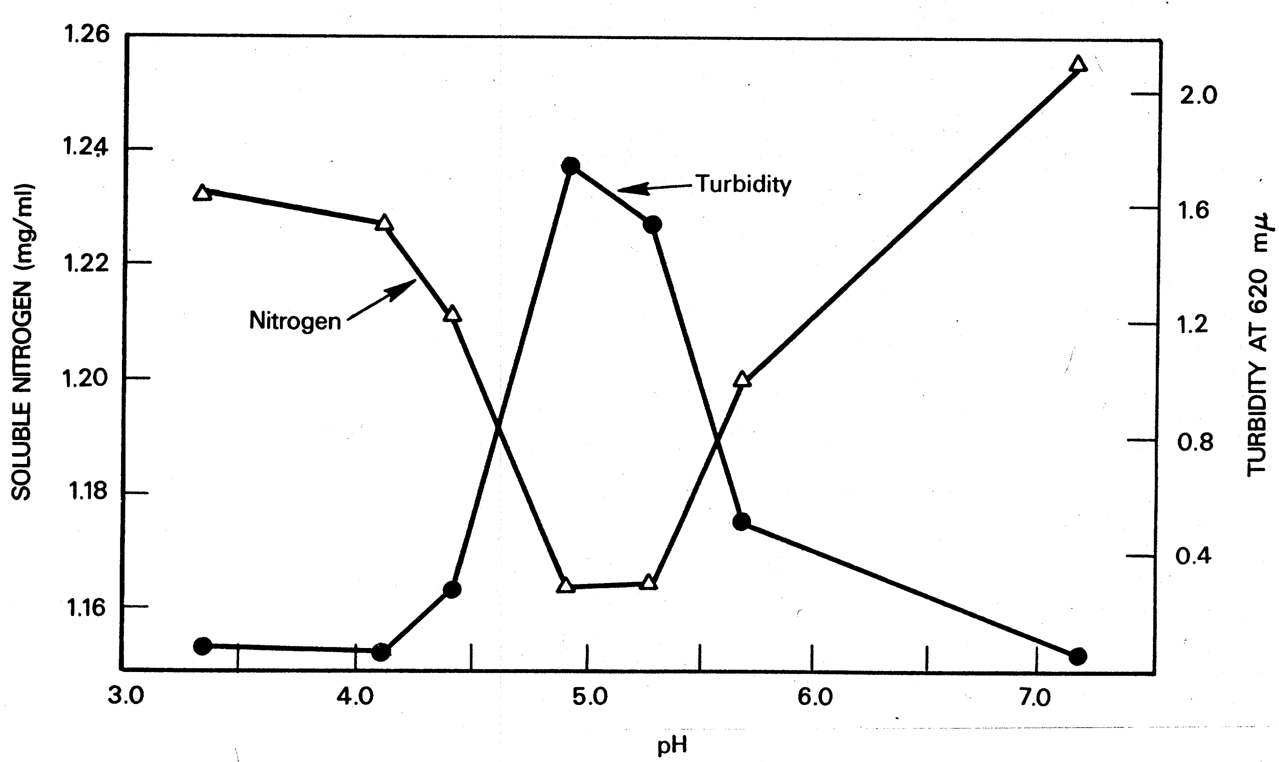

Figure 2.--Change in solubility of high-protein whey powder with pH.

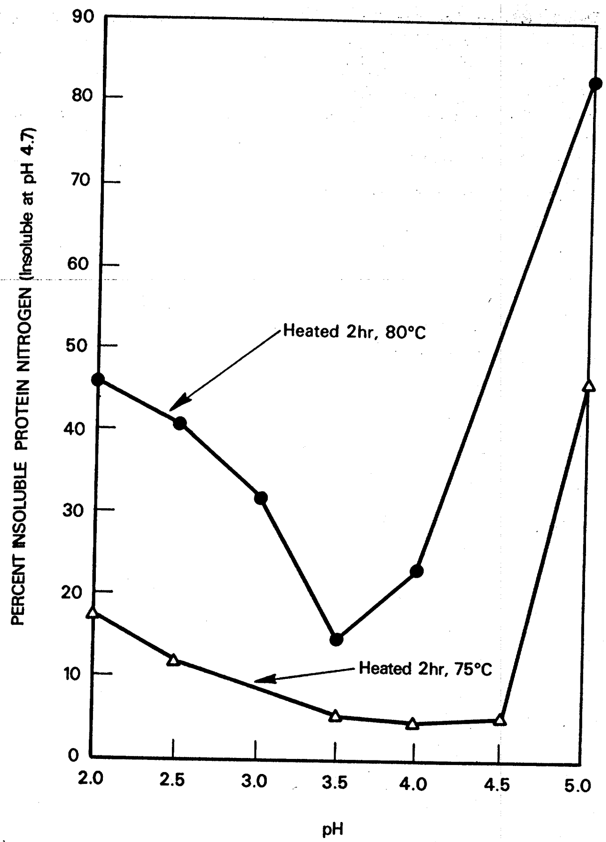

Figure 3.--The effect of acid pH on the heat denaturation of whey proteins.

solution in the lower pH ranges typical of carbonated soft drinks. This explains beverage clarity, and the data shown in figure 3 demonstrate why this clarity could be maintained over long periods of time.

The curves in figure 3 demonstrate that the whey protein concentrates are actually most resistant to thermal denaturation at pH 3.5. This phenomenon is illustrated by the rather dramatic differences in turbidity that result from heating at different pH's. Not only does this unusual stability against thermal denaturation at acid pH tend to favor the fortification of soft drinks, but many of the soft-drink ingredients themselves tend to stabilize the whey proteins that are added.

Figure 4 shows how sucrose, a popular sweetener in soft drinks, actually retards the heat denaturation of whey proteins. From these curves it can be seen that after heating for 6 hours at 80° C., the sucrose-containing solution contains only half the denatured protein found in the unsweetened control.

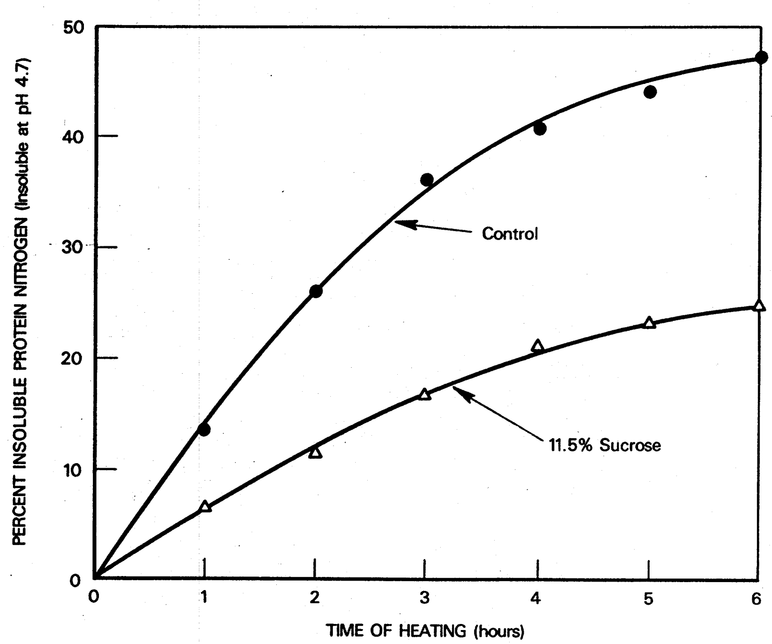

Figure 4.--Effect of added sucrose on protein stability at 80° C. and pH 3.3 when acidified with citric acid.

The type of acid used in the soft drinks can also influence whey protein stability but not quite as dramatically as added sucrose. Figure 5 demonstrates that the rate of denaturation of whey proteins in phosphoric acid solutions of pH 2.68 is less than that noted in solutions brought to the same pH by addition of citric acid.

Figure 6 shows the stability of whey proteins when heated at 80° C. in two popular commercial soft drinks. The whey proteins are less stable in the cola beverage, which has a pH lower than the point of greatest stability. The pH of the citrus beverage is very close to the point where the proteins are most stable to heat denaturation. The presence of flavorings and colorings affect protein stability only slightly in these particular products.

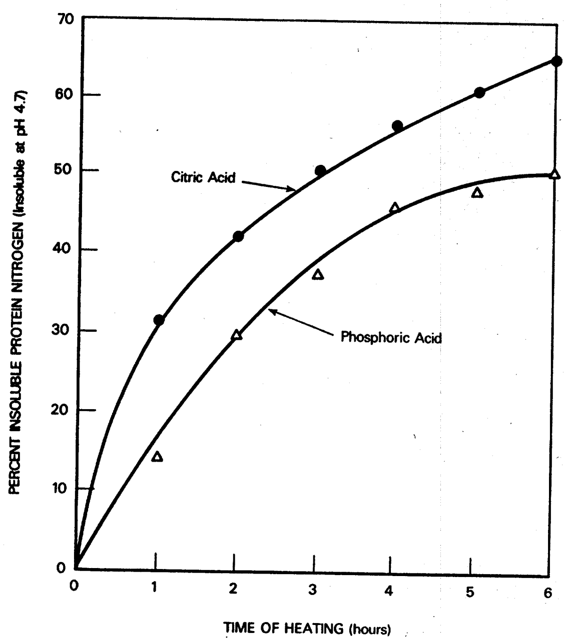

Figure 5.--The effect of two different acids on protein stability at 80° C. and pH 2.68.

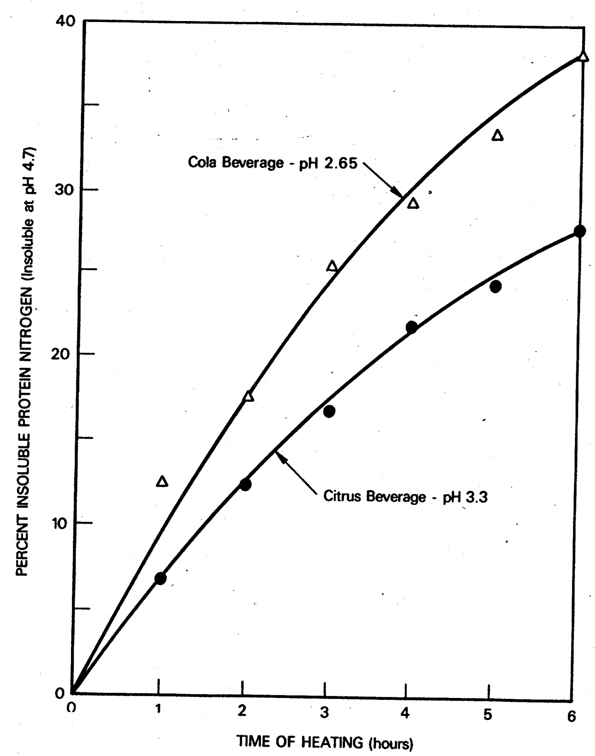

Figure 6.--Protein stability in commercial soft drinks heated at 80° C.

From these observations and data obtained in ongoing observations we believe that whey proteins can be successfully used to fortify most soft drinks if they can be concentrated undenatured at a reasonable price.

We also believe that it may now be possible to go the Rivella route and capitalize on the "natural" food movement with the development of herb-flavored carbonated beverages made from deproteinized whey. The permeate produced by the ultrafiltration of cottage cheese whey provides an excellent starting material.

DISCUSSION

QUESTION: Did you attempt more than 1 percent fortification of beverages with whey protein?

MISS HOLSINGER: We did make some beverages with 3 percent fortification, but we ran into flavor problems that appear to be typical of this product. We are working on the flavor of fortified beverages at this time.

QUESTION: Did you use proteins from both acid and sweet whey for beverage fortification?

MISS HOLSINGER: No, I used only acid whey.

QUESTION: Does a 1-percent fortification represent a sufficient nutritional improvement to justify a soft-drink company that adds protein at this level to make great claims for the health value of its beverage?

MISS HOLSINGER: Any protein at all included in a soft drink represents a nutritional improvement. Since these beverages are consumed by many in such large quantities, even a 1-percent addition should make a definite nutritional contribution.

QUESTION: Do you know of any protein-fortified soft drinks that are being test-marketed or contemplated here in the United States?

MISS HOLSINGER: There was a suggestion that such a product might be test-marketed this fall, but I don't know this as an absolute fact. I do know that several soft-drink companies are working on this possibility.

QUESTION: About what protein yield have you achieved from whey?

MISS HOLSINGER: Not a very good yield. I'd rather not say what it is at this time since we are still working on this phase of the operation. We have no final cost estimate as yet, but we expect to have one soon, and it will be published.

QUESTION: Is there any reaction of the protein with the caramel coloring in cola-flavored beverages?

MISS HOLSINGER: I think the question you are asking is, Did we have any hazing problems with caramel-colored cola beverages. Yes, we had some, but in the commercial beverages we tested we had no hazing problems at all as such. It depends on the cola beverage used. We are currently studying this problem by collecting as many caramel colors together as we can to see how our protein reacts with each one. The particular beverage I described in my talk remained clear, even after 6 hours of heating in the presence of the protein. I'm sorry, but I don't know how azo dyes would react with our protein. The only caramel-colored beverages in which I have used the protein have been carbonated.

Whey Usage in Dairy Products

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It does seem very appropriate that a good dairy product such as whey finds extensive use in other dairy products. There are already many important, large-scale uses of whey in dairy products and many more will be developed in the future.

Probably the largest single use of whey in a dairy product is in ice cream. Federal regulations permit the use of whey in ice cream up to 25 percent of the nonfat milk used, and now most States also permit this usage level. As a result, many millions of pounds of whey solids are used each year in ice cream.

A short discussion of whey usage in ice cream is desirable at this point to understand how it was developed so successfully. It was not done overnight, and many factors were involved. Originally, attempts to use whey in ice cream resulted in what was commonly called "sandy" ice cream. Lactose from the whey would crystallize in the ice cream during frozen storage and would give a gritty or "sandy" mouth feel. This problem was solved by the proper selection and use of stabilizers, which controlled the crystallization of the lactose. In addition, in early usage there were serious problems with flavor, both off-flavors due to poor handling and burned flavors due to drying methods. The present methods of handling whey for edible use, basically in just as sanitary a manner as fresh milk, assure freedom from the off-flavors associated with uncontrolled fermentation.

Also, development of satisfactory spray drying methods for whey made dried whey acceptable as an ingredient in food products, since spray drying minimizes development of the undesirable Maillard browning reaction. Whey was originally dried on roll dryers and this product was never really acceptable for use in ice cream because of its burned flavor and ever-present brown specks.

Ice cream manufacturers do know that whey can cause some texture changes, detracting from firmness in body and from smoothness. However, most ice cream manufacturers have learned to compensate for this. Regarding flavor, a good quality whey product does not change the flavor of ice cream enough to be a problem. However, if it is felt that a flavor problem exists, specially processed whey is available at a premium price. This whey has been processed by electrodialysis to remove part of the minerals and has a blander flavor than regular whey.

While I have been talking about ice cream, whey is, of course, used in other frozen desserts such as sherbets, ice milk, and various novelty items.

There are strong economic reasons for using the less expensive whey in place of nonfat milk, and it is expected that the ice cream industry will continue to use large amounts of whey solids. At present they are using both whey concentrate and dried whey. Some ice cream manufacturers who use large quantities of whey find that the concentrate is easier to handle than the dried product and can be a less expensive source of whey solids.

It is necessary to have refrigerated storage tanks and to alter processing slightly in order to use the concentrate. Minor formula adjustments may also be necessary. The storage life of properly handled whey concentrate is good, and if good sanitary practices are followed, no serious problems should arise.

One problem does still exist in using whey in ice cream, and this is a color change called "pinking." This problem is directly associated with the use of annatto, the orange coloring material used in cheesemaking. Under certain conditions, annatto changes color, making the ice cream an undesirable pink. If this "pinking" is severe, the ice cream is unsalable. One way to avoid the problem is to use whey from uncolored cheese varieties, such as Swiss, mozzarella, uncolored cheddar and a few others. Unfortunately, this problem was complicated by the fact that some manufacturers also added annatto color to ice cream in an attempt to give it a rich, creamy color. The exact conditions necessary for pinking to develop are not completely understood, and it occurs sporadically. The total amount of annatto present, along with processing conditions for the whey are factors.

Another large dairy use for whey is in cheese foods. These are softer bodied than regular processed cheese, partly because of the added whey solids, but this is a recognized and desirable feature of these cheese foods. The consumer finds them much easier to use in making sandwich fillings, such as pimento cheese. These cheese foods melt more readily and are preferred for use in sauces and, of course, in toasted cheese sandwiches. Whey is used, too, in the even softer-bodied prepared cheese spreads, which are very popular. Whey is useful in these products, because it accentuates the cheese flavor and seldom causes any off-flavor as other ingredients might.

Here again, in these cheese food uses, either whey concentrate or whey solids can be used, depending somewhat on manufacturing procedures and types of products desired. Unfortunately, as in ice cream, there is occasional trouble with "pinking."

Another quite new and potentially large use for whey is in making a "starter media" for cheese production. The bacterial culture used for making cheese is built up from small laboratory quantities to large "batch cultures" or "starters" which are then added to tanks of milk to form the cheese curd. Nonfat milk solids customarily have been used for making these bulk cultures, but the product had to be carefully selected to make sure it did not contain "phage," the bacteria disease organisms which would interfere with normal growth of the desired culture bacteria.

Nonfat milk was usually fortified with nutrients to further encourage rapid culture growth. Now, whey can be used instead of nonfat milk with good results. For example, researchers at Utah State University report that they fortified whey with yeast extract and phosphates and then heat-treated the mixture. This media produced a good starter culture and made normal cheese. Commercial products of this type are available. In general, these whey-based starter medias are less expensive than nonfat milk and are quite satisfactory.

As I mentioned earlier, one of the serious problems involving the use of sweet whey in dairy products, and in other uses as well, is the annatto color in much of the whey available. An effective decolorizing process has been described by the Dairy Products Group at USDA's Eastern laboratory. They reported very favorable results using benzoyl peroxide, and somewhat less satisfactory results using hydrogen peroxide. In terms of overall operational effectiveness and cost, the benzoyl peroxide treatment is much preferred over the hydrogen peroxide. However, FDA regulations do not permit the use of benzoyl peroxide in whey. Benzoyl peroxide is permitted in making certain types of cheese, and has been used for many years in bleaching of wheat flour, but it was never cleared for use in whey.

With all its current problems, the FDA is probably not very eager to accept new additives, but it would seem to me that all organizations involved with whey utilization--producers, users, and government agencies--should exert their influence to have benzoyl peroxide permitted for bleaching whey. The bleached or decolorized whey would have much greater economic value and its allowance would provide more incentive for salvaging whey which may now be an ecological hazard.

It is possible to remove annatto by carbon treatment and filtration, but this is a very expensive process and most of the protein is removed at the same time, so the decolorized product is not typical and has lost much nutritional value.

Perhaps the cheese industry should give some serious thought to making more uncolored cheese and using less annatto in the colored cheese which is made. Even effective bleaching of whey adds equipment and processing costs to whey, and these added costs may have to be charged back against the cheese operations ultimately.

It is not practical to add the annatto color to the cheese after whey has been separated because it is too difficult to obtain uniform coloring.

At this time, therefore, annatto colored whey remains a problem since its use in food applications is quite limited.

Up to this point we have been discussing sweet whey usage. Now it is time to talk about acid wheys and their use in dairy products. Actually, the problem of acid whey utilization may be more a problem of processing than of finding uses. Most acid whey comes from cottage cheese or Italian-type cheeses. These types are frequently made in relatively small amounts near a sales area because of limited shelf life. Therefore, the volume of whey at a given plant is small and seldom justifies the expense of installing a conventional vacuum pan concentrator. Presumably, the new techniques of reverse osmosis and ultrafiltration give some hope here, and discussion of the current work on these processes is on the program for tomorrow morning. If the whey can be concentrated economically, it can be utilized as a concentrate or dried successfully, possibly using a procedure such as the USDA gas injection spray drying method.

There are several established uses for dried acid whey in foods and some good potential uses. There are also possibilities for use of concentrated acid whey in dairy products. Cottage cheese whey, which contains about 6 percent acid on a dry basis, has been used in sherbets and other frozen desserts for several years. It has been used both as a replacement for nonfat milk and as a natural acidulant, since its acidity is compatible with fruit flavors. There is encouraging evidence now that cottage cheese whey is finally being recognized as a valuable ingredient in all frozen desserts.

I would like to quote from the March 1972 issue of Dairy and Ice Cream Field. "Pennsylvania frozen dessert standards have been amended to permit the use of cottage cheese whey, with or without modification, in ice cream, ice milk, sherbets, and nonfruit sherbets. Similar changes in frozen dessert standards are expected in New York, New Jersey, Maryland, and Delaware."

Very significantly, this change in standards opens up a much needed utilization area for cottage cheese whey, particularly where it can be used in the form of a concentrate. As an illustration, in a typical small dairy plant, where fresh milk is processed and both cottage cheese and frozen desserts are manufactured, cottage cheese whey could be concentrated and used in making frozen desserts.

However, these additional uses for cottage cheese whey in dairy products may largely replace uses for sweet whey and thus not result in a great overall increase in total whey solids use in the dairy industry. They may, however, be of significant value as an incentive for salvaging these solids at small plants.

A new use for acid whey was reported by Dr. Frank Kosikowski of Cornell University, and is proving very satisfactory. This is the use of acid whey powder as the main acidulant in the manufacture of Ricotta cheese. The Cornell work reported that 20 pounds of acid whey powder, per 1000 pounds of milk, could replace all the usual starter and give excellent Ricotta cheese. In addition, use of the acid whey powder resulted in a more complete curd formation with a 28 percent yield as compared to a 22 percent yield using lactic starter. The acid whey contains the natural dairy fermentation flavors which are desirable in Ricotta cheese. This is an excellent example of utilizing the desirable qualities of cottage cheese whey in improving an existing process.

It is worth mentioning again that the distinctive attribute of high quality, naturally acid whey is its fermented dairy flavor. This flavor cannot be duplicated by any other commercial acidulant, including pure lactic acid. It is a typical cultured dairy acid flavor and, as mentioned, this flavor is compatible with most fruit flavors, which are accentuated by it in most cases.

A challenging area for developing new uses for acid whey is in specialty cultured products, where the acidity is desired. A few years ago, a major food company developed and test marketed an imitation sour cream dry mix. This mix contained a large percentage of dried cottage cheese whey. Unfortunately, the product did not appear to meet with sufficient customer acceptance, possibly because of the dry mix form. Other imitation sour creams (not dry mixes) have been used by restaurants, apparently successfully. Along this line, yogurt-type fruit products, dairy spreads, cheese-flavored dips, and dips with other flavors are all excellent prospects for profitable uses of acid whey.

In closing, I would like to point out again that serious problems existed in the early efforts to utilize whey in dairy products and in other foods as well, but these problems were solved and have been almost forgotten. Serious problems exist today--economic, technical, and legal. These problems are under attack and will undoubtedly be resolved in some manner, too. What is certain is that whey utilization will increase as these problems are overcome.

I do hope that I have been able to show you that dairy products represent a large and successful utilization area for all types of whey, and that good prospects exist for expanding this area even further.

DISCUSSION

QUESTION: How much acid whey is permitted in the Pennsylvania frozen dessert standards?

MR. SINGLETON: This was not announced in the notice I saw. I assume it would be the full 25 percent. I think the important thing is the recognition that acid whey is as acceptable as sweet whey in these products.

Whey Solids Increasing Use in Confections

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The confectionery industry uses practically every type of milk product available. Three broad classes--fresh, concentrated, and dry dairy products--are important basic ingredients in many confections. Blends of 25 different milk products give the candy makers a varied, useful, and taste-tantalizing choice(1, 2).

For this Whey Products Conference we will discuss the use of sweetened condensed whey, powdered whey, and blends with vegetable and animal proteins.

Powdered whey, sweetened condensed whey, and blends with skim milk and soya protein are finding increased use in confections. These low-cost edible products are high in lactose and salt and are excellent for color and flavor development. Although whey lacks the protein casein, which gives body and firmness to confections, it is being used extensively in all types of confections. Whey proteins do have good foaming properties, but will not set on heating like egg proteins. But when whey is combined with soya, skim milk, or whole milk solids, very unusual and tasty confections result. What better way is there to increase the protein, mineral, and vitamin nutrients in confections?

When picking whey products or combinations, one is guided by the five basic constituents--milk fat, milk protein, milk sugar, milk minerals, and vitamins. Each of these basic constituents has exact distinguishing characteristics not found in other vegetable or animal fats, proteins, sugars, minerals, or vitamins (6).

To go into the chemical and physical properties of whey products would call for a week-long session. Most of you production men here are interested in some of the practical aspects of using whey products in your particular specialty confections. We will comment on only a few of these.

When we think of whey products in confections, we naturally think of milk-type caramels. Here a large quantity of whey is used to develop a flavor that cannot be obtained in any other way. The practical candy maker has found that slow cooking develops more of the true brown caramel color and flavor than rapid cooking. The color comes from a reaction of the proteins with lactose and dextrose and from the caramelization of the lactose with high temperatures and long cooking. Several excellent papers on this one phenomenon have been presented at previous conferences of the Pennsylvania Manufacturing Confectioners' Association (7) and the National Confectioners Association of the U. S. (3).

Table 1 gives the formulae for producing whey caramels on either a small laboratory or kitchen scale or on a larger commercial scale. These are excellent confections that can be wrapped or coated with chocolate.

TABLE 1.--Formulae for whey caramel

Ingredient	Small scale 2/		Commercial scale 3/	
	Pounds	Ounces	Pounds	Ounces
Corn syrup	5	3.52	30	
Sugar	3	4.16	10	
Sweetened condensed whey 1/			23	
Whey powder	1	9.28		
Invert sugar		13.91	5	
Soya protein		8.00	2	14
Vegetable fat 96 to 100° F.	1	9.28	9	
Vegetable lecithin		0.348		2
Salt		.696		4

1/ 38 percent whey solids, 24 percent water, 38 percent sucrose. Thus 23 pounds of sweetened condensed whey contains 8.74 pounds of whey solids, 5.52 pounds of water, and 8.74 pounds of sucrose.

2/ For small scale: Mix whey and soya protein powders and sugar slowly, adding water while mixing as necessary to maintain a thick pasty texture (14.64 ounces of water should be sufficient, but more may be added to get a mixture free of lumps). Mix corn syrup and invert sugar in mixing kettle. Add vegetable fat and lecithin and salt, mix well and cook to 244° F. Add 0.435 ounce or 12.8 ml. of vanilla flavor with added vanillin to make 6 fold. Mix and pour on slab to cool. When cool enough, caramels may be wrapped on standard wrapping machine.

3/ For commercial scale: Cook to 244° F. Add 2-1/2 ounces of vanilla and mix. Pour on slab to cool, then cut and wrap. Add burnt-sugar type caramel flavor or spray-dried caramel color if needed.

These formulae are to be used as a guide. They can be changed by using different percentage levels of any or all basic ingredients.

These whey formulae make a caramel with a fine flavor. It is possible to make a very light caramel with little or no color when only sweetened condensed whey is used. Caramels made from sweetened condensed whey and soya proteins come close to matching the flavor or texture that is imparted by the serum solids found in skim milk or whole milk. By juggling one or two ingredients, or by varying the degree of cooking, very radical changes can be made in texture, flavor, and color. Whey caramels can be coated for added sales appeal in either sweet, milk, or dark chocolate coatings made with whey powder in their formulations.

Confectioner's or compound coatings resist summertime deterioration. Widespread acceptance has resulted in year-round use. For the most part, the coatings consist of hard vegetable fats, sugar, and dried milk powder. Spray- or roller-dried whey powders are finding increased use in these products. Chocolate liquor, cocoa powder, or both, are used. Moreover, these coatings help make eye-appealing and flavorful assortments.

Chocolate coatings made with cocoa butter have excellent eating qualities. But, they bloom and are extremely difficult to temper. Present confectioner's coatings with lauric-type hard butters resist bloom and are more readily tempered. However, they are not compatible with cocoa butter in chocolate liquor. Some coating formulators substitute cocoa powder for the liquor, but at a loss in flavor value. Whey powders are compatible with chocolate liquor and increase flavor and bloom resistance.

More recent is the appearance of dietetic-type confectioner's coatings. Spans and Tweens (4) in chocolate-type coatings allow them to withstand temperatures of 140° F. And, the coatings taste like real chocolate. Dried wheys not only add protein, vitamins, and minerals, but give a tangy taste to chocolate and chocolate-type coatings.

For space foods (5), coatings contain high-melting fats (135° F.) to reduce the rate at which these bite-size products disintegrate in the mouth. These coatings help the solubility of the piece. At the same time, they do not produce a waxy sensation in the mouth.

Edible whey based coatings also work well for these "bite-sizers." Coatings made from zein (protein fraction of corn) in conjunction with whey also produce functionally acceptable coated space foods.

Some Newer Coatings

Edible coatings (Cozeen) based on non-toxic acetoglycerides and zein successfully retard rancidity and moisture absorption when used for nuts and other items. Zein-acetoglyceride coatings are applied to nuts by tumbling in a revolving pan. Evaporation of the coating's alcohol solvent is rapid, and may be speeded up by blowing air over the products during tumbling. Spraying or mixing also coats the products--so long as a thorough continuous coating is attained and products aren't broken.

Cozeen protectively coats confections, bite-sized cubes of compressed freeze-dried fruits and vegetables for the space program, raisins and glazed fruits in molded or chocolate-panned items, nutmeats and granulations in cake mix, and other mix items.

Dusting these panned or sprayed products with dried whey powder adds nutrition to them, along with a tangy flavor. Try it--you'll like it!

The whey industry is to be congratulated for holding a conference such as this. The confectionery industry is using large tonnages of whey solids, and after this conference I predict it will use even more to make tasty nutritious confections.

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Miscellaneous Human Food Uses For Whey Products

R. E. Meade

To cover the food uses for whey products left over from the more important applications discussed by the four preceding speakers, I have chosen to give what is necessarily only an outline rather than a review. If the "pickings" I will deal with appear somewhat slim, it is because I have anticipated that my colleagues would do a thorough job.

To supplement my remarks, I have prepared two lists. List 1 classifies whey products as they are now being sold as ingredients of human food, and list 2 categorizes human food uses for whey other than those that have already been taken up. Both lists, which are accompanied by references, represent an attempt to arrange whey products and their areas of use in an orderly fashion along the lines now being studied by the standards committee of the Whey Products Institute.

I acknowledge that these classifications are superficial and possibly oversimplified. However unsuccessfully, I have deliberately tried to keep them simple, on the theory that they may well be even more complicated when those with more knowledge of the subject than I are done with them. Time will not permit discussion of more than a few specific products or uses.

To benefit from what is presented here, it will be necessary for you to use the references cited for detailed or specific information of value. In preparing these classifications and references, I have depended largely on previous reviews greater in scope and more scholarly in approach. I have also benefited from some personal sources and particularly from certain individuals or groups now actively engaged in producing as well as in studying and developing new products from whey. Relative to published reviews, I recommend in particular the latest (1970) edition of Byproducts from Milk edited by Webb and Whittier, with particular reference to the chapters dealing with whey and whey products (6, 20, 28, 29, 31, 47, 48). The bibliographies for these chapters will be of much help to those interested in past efforts to utilize whey. Included are many references to processes and products, including quite a few which failed to achieve commercial success.

List 1

Classes of Whey Products (as Ingredients) for Human Food Uses

A. Whole dried (or condensed) wheys (22, 26, 44)

1. Sweet (or low acid) type (22, 34, 42, 44)
2. Cultured (or high acid) type (9, 22, 46)

B. Dry (or condensed) whey fractions (22, 26)

1. Partially delactosed (7, 8)
2. Partially demineralized[1/]
3. Partially delactosed and demineralized[1/]

C. Protein isolates and concentrates

1. Isolates containing 80 percent protein or more (27)
2. Concentrates containing 31 to 79 percent protein (8, 19)

D. Modified wheys and products therefrom

1. Yeast (2, 3, 10, 21, 51)
2. Vitamin concentrates B_2 and B_{12} (11, 24, 36)
3. Vinegar (53)
4. Alcoholic beverages (18, 53)
5. Lactic acid and lactates (53)
6. Other organic acids (53)
7. Hydrolysates (45, 50)

E. Whey blends (processed mixtures of wheys with various food materials, including fats, proteins, carbohydrates, etc.) (14, 15, 17, 19, 23)

F. Lactose (1, 16, 32)

1. U.S.P.
2. Edible (16)
3. Amorphous (28, 29, 48)
4. Beta and alpha anhydrous (41, 43)

[1/] For adding to brine to improve pickle quality. Personal communication from W. Breene, University of Minnesota Department of Food Science.

List 2

Other Human Food Uses for Whey[1/]

A. Infant and weaning foods (1, 4, 7, 8, 23)

B. Other "nutritional" foods (8, 27, 37, 39, 40, 51)

1. Health foods or instant breakfast types (8, 12, 27, 33)
2. "Natural" and "organic"
3. Geriatric and juvenatric (12)

C. Fortification or filler applications (possibly overlooked in beverage area; for example, addition of lactose to skim or low-fat milk) (1, 12, 32, 37, 39, 40)

D. Imitation or simulated milks (milk and skim-milk substitutes containing lactose, which is classified as a chemical) (12, 48)

E. Functional additive or ingredient

1. Acid whey as an ingredient in cheeses, such as Ricotta (9, 14)
2. Lactose as additive to pickle brine (at 6 percent level)[2/]
3. Lactose as desiccant or moisture scavenger in sugar coating, frostings, fondants, etc. (13, 48)
4. Protein as film former in foams and emulsions (17, 35, 38)
5. Lactose as carrier in low-calorie sweeteners (33)
6. Lactose as seed in sweetened condensed milks (43)
7. Whey products in coffee creamers or whiteners (48)
8. Acid whey as ingredient in citrus beverages (15)
9. Fermented products as source of vitamins (11, 24, 25, 51)
10. Fermented products as flavor component (10, 21)

[1/]Other than in baked goods, beverages, dairy products, and confections. These uses are covered in the preceding papers in these proceedings.

[2/]See footnote, List 1.

This book, however, is marked by a deficiency, or oversight, that is peculiar to most of the publications by learned scientific authors, most of whom are associated with Government agencies or educational institutions. Typically in the technological literature, in spite of numerous references to technical developments, including patents, there are few if any references to certain patented products and processes which have contributed the most to commercial success--to the track record, so to speak. This is particularly apparent in the omission of references to the specific patents pertaining to lactose, dried whey, and demineralized whey processes. These are patents that are actually in use, are known to account for the major portion of U.S. industrial production of these products for the past 20 years, and have established the owners and licensees in their present dominant position. There is really no mystery in identity here, and I am perennially shocked that industrial technology has been so little recognized in the U.S. literature. I suppose those who write about the subject have agreed among themselves that profitable technology needs no other reward. Some of these valuable patents, having recently expired, are now being widely employed throughout the rest of the world as well as, to a lesser extent, in the United States. An effort has been made to cite some of these patents in this bibliography (1, 5, 10, 22, 23, 32, 34, 42, 44).

Also cited in the bibliography are several valuable reviews of the subject. These include three Australian reviews, one by Osburn (30) and two by Wix and Woodbine (53). In these papers, the Aussies cite the leaders. Another important review was presented at the Whey Utilization Conference in 1970 (54). In this paper the most widely used process for whey drying in the United States was described, but the key patent, which expired in 1970, was not cited. Other valuable reviews are those on lactose by Weisberg in 1934 (50) and on the utilization of whey by Webb and Whittier in 1948 (49).

I also wish to thank certain individuals who have helped me directly by supplying information pertinent to whey products or processes developed by their research. These include Dr. M. J. Pallansch, chief of the ARS Dairy Products Laboratory in Washington, D. C., who provided information about his staff's work on high-acid whey; Dr. Frank Kosikowski, professor of food science at Cornell University at Ithaca, N. Y., who provided copies of several publications on uses for acid whey that resulted from the extensive work done under his direction; Dr. Bromley M. Mayer, director of research for the Knudsen Corporation in Los Angeles, who provided information of dried whey-grown yeast and a copy of a review on whey uses; and Dr. Paul Sharp, who in the late 1960's provided information relative to the manufacture and use of crystalline lactose anhydride.

To my knowledge there are only two other uses for whey products not previously considered that are of substantial commercial importance. Both of these are quite large as well as relatively essential. The first, infant foods, is long established and has a steady growth record for the past 20 to 30 years in its use of lactose, demineralized whey, and whole whey. Infant foods have been traditionally considered the largest use for U.S.P. and edible grades of lactose, probably now consuming more than 35 million pounds annually. In addition, demineralized whey is supplied for infant food formulas in quantities estimated at 10 to 12 million pounds per year.

Another new use for lactose is as an addition to skim or low-fat fluid milk. This use is probably less well known, but nevertheless it is of substantial current, and even greater potential, magnitude. Approval of lactose as a skim-milk additive has been granted in many areas by Government regulatory agencies. Correspondence from the U.S. Department of Health, Education and Welfare to milk inspection supervisors has authorized the addition of U.S.P. and edible lactose to grade A milk and milk products. The use of lactose in place of nonfat dry milk should be considerably stimulated by its lower price (currently 50 percent lower). No precise figures are available for this usage, but I would guess it may exceed 25 million pounds in 1972. In view of the regular growth of low-fat fluid milk consumption, this offers a large potential for the future.

Since cost is such a critical factor, one wonders if consideration has been given to using dry sweet whey as an additive to increase the solids in fluid low-fat and skim milk. At levels up to 1 percent, I should think it would be preferred to lactose. Acid whey might also be an excellent additive for cultured grade A buttermilk. I suppose it would take some missionary work among the Government agencies to establish approval, but it should be worth a major effort. It would reduce the cost of buttermilk and at the same time supply high-quality protein at a lower total lactose level.

Most of us here are concerned with the matter of total usage of whey, a worthwhile concept, to halt waste and eliminate pollution. Hence, other than the specific items mentioned in lists 1 and 2, I will not attempt to deal with the many and varied whey products and uses of little or no importance which are covered in the bibliography. I will leave these for you to discover and perhaps enjoy as unrealistic curiosities of the past.

Since my assignment is "other uses," and because there are still a few minutes of my allotted time available, I will try to relate the foregoing to the frightening threat of surpluses resulting from total utilization. I can begin by pointing out that the answer to the industry problem is simple to state. The undeniable answer is "A vast increase in use of lactose." It must be recognized and realistically accepted that 70 to 75 percent of the substance recoverable from whey is LACTOSE.

I do not deplore or belittle the excellent, widespread, and much publicized research devoted to recovery of whey protein. This work has resulted in elegant, sophisticated processes and products which have been and will be reviewed again at this meeting. By these methods it is possible to recover quality protein with a high protein efficiency ratio and with excellent flavor and functional properties. So far, costs of such products appear to be high, but their value appears to be at least equal to casein for food applications.

The real problem comes into focus when it is realized that for each pound of such superior protein the industry must find markets for 8 to 10 pounds of lactose or its equivalent in some form. It seems doubtful if the value of this small amount of protein will be enough to subsidize the lactose, a carbohydrate with admitted limitations, based on present knowledge. Various estimates have indicated approximately 40 to 50 percent utilization of current whey supplies. Based on USDA figures for 1971 (1972 figures are higher), I would estimate at least 700 million additional pounds of whey solids, containing 500 million pounds of lactose, would result from total whey utilization. From my own past experience, these are very impressive figures.

In 1940 U.S. lactose production was only 7 million pounds. In 1970 it was estimated at 105 million pounds, with another 10 million pounds imported and 5 million pounds exported, leaving about 110 million pounds available for disposition. (These figures include edible and refined lactose as well as crude lactose, whether edible or inedible.) Table 1 shows how such quantities of lactose as these might be used, with both minimum and maximum amounts for each use. The mean figures lying between these minima and maxima would roughly take care of the entire production. The maximum figures show the possibilities of disposing of much of the large additional quantities that would be made available as wider use is made of the newer fractionation processes to produce protein products from whey.

In spite of these potentials, absorption of such increased quantities of lactose will require "other uses" of great magnitude. I am sure none of you in this audience came expecting to learn how to get around this impasse from any of us on this program--certainly not from me! If such a breakthrough is achieved, it is likely to come from a basic, fundamental development as a result of a new, unique approach.

The potential "OTHER USES" which we can dig out of the literature and statistics are feeble indeed in relation to the need. Furthermore new lactose uses must overcome or resolve the low sweetness, low solubility, alleged digestive intolerance, adverse reducing properties, and low osmotic pressure that are now considered limiting factors in its use.

Any scientific or technological "breakthrough" must therefore achieve vastly expanded markets to be considered a significant or important contribution. Process innovations are meaningless unless they provide for greater consumption through:

1. New products contributing (at reasonable costs) greater essential functions, values, and utility.

2. Cost reduction, sufficient to overcome competition from the less expensive, sweeter, and possibly more functional, carbohydrates. The only alternative is some form of subsidy, a prospect some will consider undesirable, unrealistic, and unlikely.

Admittedly the prospects are not encouraging, but there are some characteristics of this so-called "disadvantaged" carbohydrate which make it worth exploring. Perhaps because it is different, lactose may offer opportunities greater than its limitations. For example, in the early phase of penicillin production, lactose was the preferred and essential carbohydrate. Its disaccharide composition offers advantages in various other systems as well.

TABLE 1.--Estimated quantities of lactose for which known end uses might provide a market

End use	Quantity (thousands of pounds)		
	Minimum	Maximum	Mean
1. Infant foods	30,000	40,000	35,000
2. Pharmaceutical (diluent for drugs and medications)	15,000	25,000	20,000
3. Fermentation media ingredient (use determined by price)	4,000	20,000[1/]	12,000
4. Miscellaneous food additives (includes low-calorie sweeteners)	10,000	12,000	11,000
5. Fortified low-fat milk and beverages	10,000	50,000[2/]	30,000
6. Military (smoke, flares, etc.)	500	1,000	750
7. Other miscellaneous uses	2,500	3,000	2,750
TOTALS	72,000	151,000	111,500

[1/] When price is <$0.08 (currently quoted at $0.16 per pound).

[2/] When price of nonfat dry milk is higher than that of lactose, as at present.

Lactose is generally recognized to have unique water activity properties, as well as stability under certain conditions where the characteristics of sugar are needed. It is a superior "sugar coating" for high-moisture foods when used in combination with concentrated sweeteners. Its contrary performance in dehydrating processes sometimes is difficult to anticipate and it is often influenced unpredictably and unexpectedly by the presence of other materials. Conversely, in concentrated milks it has a dramatic influence on other components. One or more of these unusual features may well be the key to our basic need. The stakes may be quite high for the necessary research funding, but most of the chips for many of you here are already in the pot. It would seem wise to wager a few more chips on lactose.

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Utilization of Whey–Grain Blends by Calves

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A feed ingredient may perform several functions in an animal's diet. In addition to supplying protein, energy, vitamins, minerals, and unidentified growth factors, it may also increase palatability, reduce dustiness, act as pellet binder, provide necessary bulk and (in the case of feed for ruminants) maintain normal rumen function. Maintenance of normal rumen function would include prevention of parakeratosis, maintaining normal milk fat content and stimulation of rumen papillary growth. In determining the best use of whey in animal feeds, all of these functions should be kept in mind.

In evaluating dry whey as a supplier of nutrients, a comparison with milo (table 1) will be useful.

TABLE 1.--Gross composition of milo and dry whey[1/]

	Protein	Fat	Nitrogen-Free Extract	Minerals	Moisture
Whey, dried	12.2	0.8	70.4	9.9	6.5
Milo grain	11.3	2.9	71.3	1.7	10.6

[1/]Morrison, F. B., Feeds and Feeding, 21st ed., 1950.

The protein and energy content of milo and dry whey are similar and since milo is usually available for around 2¢ per pound, it is apparent that whey will not find a significant outlet on the basis of the quantity of these two nutrients supplied. However, the quality of the whey protein, the desirable features of the lactose, as well as the amounts of vitamins and minerals should be capitalized on.

Early rumen development in calves is very desirable and since rumen development depends on dry feed consumption, palatability of dry feed for calves is very important. Recently, research has been conducted at Kansas State University to determine what effect dried whey and other milk products have on the palatability of dry calf feed and on the ability of that feed to stimulate rumen development. Experiments have been conducted using various levels of sweet dried whey, partially delactosed whey, and partially demineralized whey in calf starters. The different products being tested have been used in various formulations to determine the importance of nutrient interactions. Type and amount of roughage and level of minerals have received special consideration.

A typical basal formula used in these tests is as follows:

Sorghum grain	33	percent
Alfalfa	25	"
Corn	10	"
Oats	10	"
Wheat bran	10	"
Soybean meal	5	"
Molasses	5	"
Fat	2	"
Vitamin A	2500	I.U./lb.
Vitamin D	1000	I.U./lb.
Antibiotic	15	mg./lb.

Various levels of the different wheys being tested were incorporated into the ration and the effect on palatability determined. Four feeds were evaluated in each experiment; the palatability of each of the feeds was compared to that of each of the others, two at a time.

The research is only partially complete and therefore no definite conclusions can be drawn at this time. All of the milk products tested have been successfully used in our self-feeding program. Levels as high as 40 percent dried whey have been used. Mixtures with as much as 30 percent have been pelleted without difficulty.

Representative data from 6 of the experiments are shown in table 2. Each value is the amount of that feed consumed in one week. A similar amount of another feed was consumed.

The results indicate that, while the products tested may have increased palatability of some mixtures, in general they were without a profound effect. More research will be needed to fully evaluate the effect of using whey products in whey-grain blends for young calves.

TABLE 2.--Effect of different levels of whey on consumption of calf starters

Whey		Amount consumed in each week (pounds)						
Treatment	Percent	1	2	3	4	5	6	Average
Dried	0	0.6	1.4	2.4	2.7	4.5	4.8	2.7
	5	0.5	0.7	2.0	3.6	3.3	2.8	2.2
	10	0.5	0.8	2.4	5.2	4.0	9.3	3.7
	15	0.4	1.7	2.6	3.7	5.7	6.2	3.4
	Average	0.5	1.1	2.4	3.8	4.4	5.8	
	0	0.6	0.7	2.0	1.8	2.8	5.7	2.3
	10	0.6	1.4	1.8	3.4	2.6	5.6	2.6
	20	0.6	1.4	2.5	5.6	7.4	9.5	4.5
	30	0.7	2.2	3.6	3.8	6.6	9.7	4.4
	0	0.2	0.5	0.7	1.3	1.6	2.2	1.1
	13.3	0.2	0.1	0.6	2.8	3.4	3.8	1.8
	26.7	0.4	1.6	3.0	3.0	3.2	8.4	3.3
	40	0.6	1.4	1.5	3.0	3.8	6.6	2.8
Partially delactosed	0	0.1	0.6	1.8	2.2	5.8	5.3	2.6
	8.3	0.3	0.6	2.2	3.1	3.4	8.0	2.9
	10	0.2	0.7	1.4	3.1	5.0	4.9	2.6
	15	0.3	0.6	1.6	3.2	4.7	8.6	3.2
	0	1.0	2.0	3.0	3.7	5.1	8.8	3.9
	5	0.4	1.0	3.7	3.5	4.0	8.0	3.4
	10	0.4	2.6	2.0	2.2	3.8	6.0	2.8
	15	0.3	0.5	1.6	2.4	2.7	4.5	2.0
Demineralized	0	1.0	2.5	3.2	5.4	6.5	9.6	4.7
	10	0.2	0.3	2.2	1.9	2.4	2.4	1.6
	20	0.2	2.0	3.6	4.3	6.6	6.0	3.8
	30	0.8	2.6	4.6	6.0	3.8	11.2	4.8

DISCUSSION

QUESTION: How old were your calves when you started your experiment, and did you find any calves that started to ruminate earlier than the others?

DR. MORRILL: They were generally three days old at the start of the experiment. Yes, some did start to ruminate before others, no doubt depending on the time they began to eat the dry feed.

QUESTION: The grain consumption in all your studies appears to be quite low. Can you give us some indication as to why it was so low and what gains you noted during the 6-week period?

DR. MORRILL: Remember, the data I showed represented only half of the consumption, since a similar amount of another feed was consumed along with it. Gains were normal in all these experiments. I don't think any gained less than a pound per day over the period of the experiment.

Feeding Liquid Whey to Dairy Animals

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The composition and virtues of whey have been amply identified and explained by other speakers at this and other conferences. Therefore, there is no need for me to do the same. In spite of all the desirable attributes of whey, it has one outstanding drawback: it is awfully wet. It is so wet, in fact, that if you move it very far, transportation costs soon exceed its residual value for any known purpose. On the other hand, if you remove the water, the costs increase to the extent that it may become prohibitively expensive for some of the purposes which could potentially utilize the largest amounts of whey. This is especially true for small plants which do not have a sufficient volume of whey to justify the cost of even minimal drying equipment. Because of these basic limitations we at the Beltsville Center have been interested in methods of utilizing whey that would avoid either drying or transporting the product very far. This interest has led us to experiments in the direct utilization of liquid whey by farm animals.

Direct utilization of liquid whey by farm animals is, of course, not a new idea. Traditionally, however, the major direct farm use has been by swine. This was a logical usage because swine are simple-stomached animals that efficiently utilize soluble material of this composition. Also farms were more diversified and many dairy farmers also raised swine. More recently, both dairy and swine farming have become more specialized and the centers of specialization have frequently been hundreds of miles apart. Therefore, it is no longer realistic to expect to feed a large amount of liquid whey to swine because of the transportation costs involved. Dairy cows, on the other hand, are seldom very far from milk processing plants. Thus the possibility of recycling whey through the cows that produced it is suggested by economics, geography, biology, and logic.

Up to this point we have been involved with feeding sweet whey, acid whey, concentrated acid whey, and some low-protein whey permeates. Most of these efforts have been cooperative with personnel of the Eastern Marketing and Nutrition Research Division, who developed the sources of whey or whey products, and personnel of the Dairy Cattle Research Branch, who have undertaken the nutritional evaluations.

LIQUID WHEY FOR DRY COWS

Our first experience with feeding sweet whey to dairy cattle started in the fall of 1970 using three dry cows. Whey was provided in tubs in lieu of water and in addition to the cows' regular ration of high-energy pellets (table 1) and hay. This regime was imposed for 70, 133, and 140 days for

TABLE 1.--Formula and estimated composition of pellets

Ingredient	Weight (kg.)	Dry matter (pct.)	Dry composition			
			Digestible protein (pct.)	Digestible energy (Mcal./kg.)	Calcium (pct.)	Phosphorus (pct.)
Corn, dent, #2 cracked	272.4	89.0	7.5	4.01	0.02	0.35
Alfalfa, dehydr. 17 percent crude protein	90.8	93.0	15.0	2.73	1.43	0.30
Soybean meal, mechanically extracted	45.4	90.0	41.4	3.75	0.36	0.75
Molasses, cane	22.7	75.0	2.4	4.01	1.19	0.11
Digestible calories	2.7	96.0	-	-	23.13	18.65
Limestone, ground	1.8	100.0	-	-	33.84	-
Salt, trace-mineral	4.54	100.0	-	-	-	-
Vitamin A (10,000 I.U./g.)	.20	-	-	-	-	-
Total	440.5					
Weighted average		89.4	12.4	3.66	0.72	0.49

the three cows, respectively. Whey consumption was not high, typically in the 25-30 kg./cow/day rate. This level of consumption may be explained by the fact that temperatures were relatively low and the animals were well fed with hay and pellets. Although all cows had loose feces their average weight gain was more than 1 kg./day. They remained in good health except for one animal that was afflicted with toxemia, apparently as a result of drinking too much whey on the day after a temporary exhaustion of the whey supply.

Feeding value of the whey consumed was not calculated by difference because such calculations would have been of questionable value. The cows received sufficient conventional feeds to meet their maintenance and pregnancy requirements; therefore, whey feed values could only be expressed as liveweight changes. From these observations we were convinced that sweet whey could be fully substituted for water and was not likely to be detrimental to dry dairy cattle at least over these short periods of time. Both of the cows, which were pregnant, calved normally although both were about 9 kg. lighter than in prior and subsequent pregnancies.

LIQUID WHEY FOR MILKING COWS

One of the cows fed sweet whey during the dry period was continued on acid whey feeding during the following lactation which lasted for 344 days. This one cow experiment was conducted in order to obtain preliminary information on any physiological problems that might develop and to obtain estimates of the nutritional value of the whey used.

After freshening, this cow was kept in a box stall with acid whey provided in a tub at all times. No water was available in the box stall but the cow did walk past a water source twice each day on the way to the milking parlor after about the fourth month of lactation. The rest of her ration consisted of complete pellets (table 1) and 4 kg. of alfalfa-hay per day. The pellets were nutritionally complete but they depressed butterfat content since they were small and high in grain content. They were fed _ad libitum_ through the first six months of the lactation and then were restricted to observe the effect on whey consumption and because the cow was gaining a considerable amount of weight. Whey consumption was over 100 kg./day in the first 3 months of lactation then dropped to less than 50 kg. in the latter part of the lactation.

Since there was only one cow and the management varied considerably, only the lactational totals are provided in tables 2 and 3. Production responses are shown in table 2, while feed consumption is given in table 3. As shown in table 2, provision of the whey did not fully correct the depressed butterfat that was characteristic of the high-concentrate, pelleted ration. Total production of milk, however, was very high where the cow had access to the whey.

TABLE 2.--Effect of feeding acid whey on the lactation performance of an individual cow

Lactation	Live weight, kg.			Milk production, kg. (305-day mature equiv.)	Butterfat	
	Initial	Final	Average		Percent	kg.
1. No whey	550	546	548	7,749	3.93	305
2. No whey	608	584	596	8,288	3.54	293
3. Whey	685	616	644	8,863	2.85	253

TABLE 3.--Feed consumption of cow fed acid whey

Feed	Total kg.	Daily kg.
Complete pellets	2,352	16.3
Hay (alfalfa-grass)	1,329	3.9
Acid whey (fed *ad lib.*)	26,864	78.1 (avg.)

The following complete, 344-day, calculations were made to estimate the feed value of the whey based on the third lactation data. The factors used are considered reasonable, although they are admittedly arbitrary to some extent:

Requirements, digestible energy

Maintenance	19.7 Mcal. x 344 days	+	6,777 Mcal.
Milk	1.20 Mcal. x 9,190 kg.	+	11,028 Mcal.
Live weight loss	10 Mcal. x 69 kg.	-	690 Mcal.
	TOTAL		17,115 Mcal.

Nonwhey feed intake, digestible energy

Pellets	3.3 Mcal. x 2,352 kg.	7,762 Mcal.
Hay	2.25 Mcal. x 1,329 kg.	2,990 Mcal.
	TOTAL	10,752 Mcal.

Value of consumed whey

Digestible energy	6,363 Mcal.
Barley equivalent	1,758 kg.

are a source of the whey, in most cases are raising replacement heifer calves and, if the economics were favorable, could easily expand into the production of dairy beef from their bull calves. Several experiments have been conducted which will be reported more fully later in the summer (1). In these experiments we usually started with calves about 6 weeks old weighing 52-55 kg. and fed until they weighed about 136 kg. The protein was provided either in the form of dry pellets or mixed in as a part of the liquid whey. Generally, fortification of whey with protein to provide a complete liquid feed has not been as successful as supplying the supplements as dry feed. Both acid and sweet whey have been used and it appears that both can be fed satisfactorily if properly supplemented with other nutrient sources. Two management problems were associated with feeding whey to these calves. One was the possibility of serious bloat when the whey supply was exhausted for a few hours and then replenished. The other was the accumulation of flies, which are strongly attracted to the whey.

Although it is feasible to feed acid and sweet wheys to calves and obtain normal growth, this type of utilization may not represent a major pathway for solving the whey disposal problem. This point is illustrated in figure 1. These values represent average results from several trials in which both acid and sweet whey were generally fed to calves in the 52-136 kg. weight range in the manner previously described. It may be seen that in the early phases of these trials, whey represented the major source of nutrients, but that within 2 or 3 weeks the relationship between whey nutrients and conventional dry feed nutrients had reversed. From that point on, major increases were made in the consumption of dry feed nutrients. The overall result is that relatively small amounts of whey dry matter are being consumed per animal. This is true whether the amount is expressed in absolute terms, as in this case, or as a percent of the total ration. Although the original objective was to supplement whey with proper dry feed, in actuality it became a matter of supplementing dry feed with whey. From the standpoint of animal husbandry, these liquid wheys may represent an excellent source of feed materials that can be used in limited amounts. However, from the standpoint of solving an industry disposal problem, it is doubtful if animals of this size (52-136 kg.) and age can make much of a contribution. Presumably the intake of whey by calves could be increased by limiting other feeds. However, the relationships between such limitations and rate of gain have not been determined.

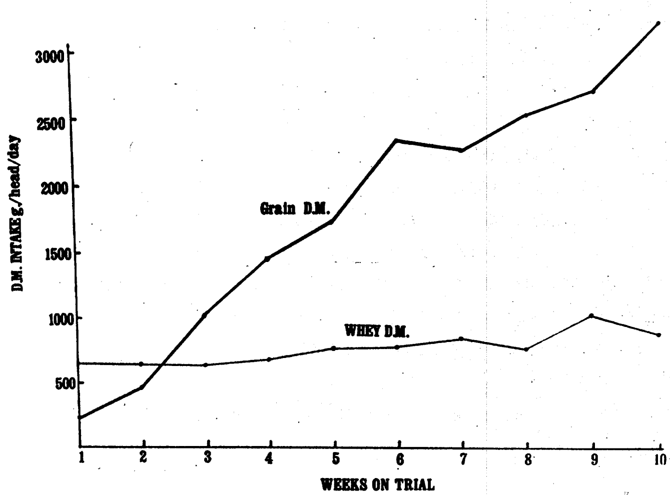

Figure 1.--Average grain and liquid whey dry matter intakes of bull calves.

We have also undertaken the nutritional evaluation of whey permeate for calf feeding. This permeate is the remainder of acid whey after most of the milking cows this whey could be recycled by returning it to about 25 percent of the producing farms which are shipping milk to a particular plant. In view of the uncertainties, added equipment requirements and inconveniences associated with establishing a whey feeding system, farmers will probably be interested in adopting such systems only on a no-charge basis. However, the processors may find this to be a least-cost method of disposal. Further research is required to more fully evaluate the potential of whey feeding to dairy animals.

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Dried Whey in Calf Feeds

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While the assigned title for this presentation is "Dried Whey in Calf Feeds," my primary emphasis will be more specifically in the area of calf milk replacer formulas.

During the 21 years that I have been associated with the whey industry, uses for dried whey in animal feeds have changed or shifted quite drastically. Up to the early 1950's, the major tonnage of dried whey was used in poultry rations as a natural source of water-soluble vitamins and unidentified growth factors and for disease control. In addition, a sizeable quantity of condensed whey was used in the feeding of poultry. Some whey was, of course, being used in calf milk replacers but the quantity was small since the milk replacer industry was in its infancy and milk replacer tonnage was small.

In the early 1950's, an erosion of the market for dried whey in poultry feeds began to take place. B-Vitamins produced through fermentation provided more economical sources of these essential nutrients; unidentified growth factors became identified or were found to exist in other feed materials which were either lower in cost or more desirable in other nutritional respects for poultry; and antibiotics as feed additives took over the problem of disease control. With these developments and the recognized inefficient utilization of lactose by our feathered friends, it became increasingly difficult to demonstrate a real nutritional need for dried whey in poultry feeds.

At this time, some people in the whey industry recognized that if a sound, stable market was to be established for dried whey in animal feeds, it would have to be based on applications where a real need for lactose or benefit from lactose could be demonstrated. Dried whey is composed of over two-thirds lactose.

Research attention began to be directed toward improved calf milk replacer formulas as well as the development of better starter and pre-starter feeds to permit earlier weaning of baby pigs. Many research studies of various carbohydrates demonstrated conclusively that lactose is the carbohydrate of choice for very young pigs and calves. This finding is not at all surprising in view of the fact that lactose is the natural carbohydrate received by these baby animals in their mother's milk. More significant than showing the efficient utilization of lactose, these research studies revealed an extremely limited ability of the very young pig and calf to utilize any carbohydrates other than lactose and glucose. The feeding of sucrose was shown to induce severe diarrhea since the baby calf is devoid of sucrase activity. Maltose and starch were shown to be poorly utilized, again because of very low activity of pancreatic amylase and intestinal maltase in the very young calf.

With lactose established as the preferred carbohydrate for young pigs and calves, it was logical that the animal nutritionist should look to dried whey. This is not only the most readily available and most economical source of lactose, but the whey also provides some excellent quality protein. As a result, baby pig and calf formulas have today become the major animal feed markets for dried whey. Total milk replacer tonnage has grown steadily and dried whey usage in milk replacers has increased at an even more rapid rate. This has been due to the progressively higher price levels of dried skim milk and the resulting use of alternate protein sources which are higher in protein content than dried skim milk. The use of these higher protein ingredients left more room in the formula for dried whey so that the percentage of dried whey in milk replacers has increased concurrently with the increase in total milk replacer tonnage.

The development of a sound market for dried whey in calf milk replacers did not come about, however, without considerable research and marketing effort. Research by whey processors, universities, and feed manufacturers was necessary to dispel the long-prevailing misconception that "dried whey was dried whey" and that whey was a standard commodity, the same regardless of where it was derived or how it was handled and processed. This conception grew from the earlier use of whey in poultry feeds where it was used at a very low level and quality differences between wheys were not readily apparent.

The picture became much different as whey moved more extensively into calf milk replacers where use levels of as much as 50 percent or more became desirable from both a nutritional and economic standpoint. Fifteen years or so ago, it was not uncommon for some research workers to state that the use of dried whey in calf milk replacers should be restricted to a maximum of 15 percent of the formula since higher levels were likely to cause a laxative effect or diarrhea. Ironically, this laxative effect was usually attributed to the high level of lactose in dried whey in spite of the fact that lactose is the natural carbohydrate for the baby calf.

Unfortunately, such comments are still occasionally made today by persons who are simply citing from the literature without recognition of differences in quality of dried wheys.

The research which indicated that dried whey should be restricted to 15 percent maximum in calf milk replacers was probably correct for the type and quality of whey used in the experimental work. The inaccuracy was in attributing the observed laxative effect to lactose when the problem was more likely due to other factors of dried whey quality. I say this without benefit of direct knowledge of the quality of dried whey used in some of this older research work. However, more recently dried whey of known high quality has been used in research studies and commercially at levels well in excess of 15 percent without adverse effect. This evidence strongly supports the contention that lactose is not the factor restricting use level of dried whey in milk replacers.

I have already commented on research studies which have shown that the baby calf is well equipped to digest lactose. They also show that calves do not effectively utilize polysaccharides such as starch, or sugars such as sucrose and maltose, until the calf is at least one month of age. Also, research on enzyme secretion by the young calf has shown high levels of lactase at birth, little evidence of maltase activity, and no sucrase or amylase activity. Interestingly, Huber and associates (1) at the Virginia Experiment Station found that intestinal lactase levels increased as increasing amounts of lactose were added to the diet of young calves. While lactase activity in the small intestine normally declines with age, this work indicated that lactase secretion is regenerative and responds to increased levels of dietary lactose.

Some light was shed on the question of the level of dried whey that can be used satisfactorily in milk replacers by workers at Michigan State University (2). They conducted experiments to determine the protein requirement of calves during the milk replacer feeding period. Protein levels of about 30, 24, 19 and 16 percent were fed. To reduce protein content, dried whey and glucose were substituted for dried skim milk. The lowest protein diet contained 52 percent dried whey. While inadequate protein reduced growth performance on this diet, no adverse effects of diarrhea or scours were found with the 52 percent level of dried whey. This was a sweet dried whey, low in acidity and unneutralized so that it contained only the natural mineral components of whey.

More recently, Morrill and associates (3) at Kansas State University reported on experimental work on the use of whey with soy protein concentrate as a substitute for dried skim milk in calf milk replacers. The experimental diets contained about 59, 68, and 76.5 percent sweet dried whey. Their results indicated that good quality dried whey can make up at least 68 percent of a milk replacer formula. At the 76 percent level of dried whey, no adverse effects were noted other than a reduced rate of gain. It would be a matter of interpretation as to whether the reduced gain was due to the higher level of dried whey or to the lower level of milk protein in the 76 percent whey diet. The latter would seem to be the more logical factor accounting for the reduced performance level.

These research data, along with commercial usage, have demonstrated that good quality dried whey can be used extensively in calf milk replacers provided there is adequate supplementation of proteins to meet the dietary requirements of the calf. It is known, however, that quality differences can significantly affect calf performance; and that some types or qualities of dried whey can require restriction on use levels.

The quality factors include:

1. Ash and acidity content: These factors are usually considered together since they may be related in processing. High acid wheys are unpalatable to baby animals so that acid content can restrict the use level. If the acid is neutralized prior to drying, the ash content of the whey may be increased to a point where ash becomes the restricting factor.

Extensive trials have been reported from Germany on the use of acid whey and neutralized acid whey in calf milk replacers (4). These workers concluded that acid whey can be used in milk replacers providing it does not exceed 15 percent of the formula. The work supports the contention that factors other than lactose restrict the use of dried whey in milk replacer formulas.

2. Heat damage: Excessive heat in processing damages the nutritional quality of dried whey more than anything else. It reduces protein quality or amino acid availability as well as solubility.

3. "Browning" reaction: The Maillard reaction between reducing sugars and certain amino acids is commonly called "browning." It results in binding or making unavailable some of the amino acids, particularly lysine. It also turns dried whey to an undesirable brown color with markedly reduced palatability to baby animals. The browning can result from overheating of whey during processing, or it can occur in storage if the moisture content of the dried whey is too high. In either case, the browning must be considered a restricting factor to use level in critical baby animal feeds.

4. Moisture: Excess moisture in dried whey, or hygroscopic wheys which may pick up moisture subsequent to drying, can pose some physical problems, even though nutritional quality may be satisfactory. Such wheys are, of course, more subject to browning and its resultant deterioration of nutritional quality. Aside from this, the high moisture or hygroscopicity can result in caking of the whey or of the final formula into which the whey is incorporated. Thus, moisture content might restrict the use or use level of a particular dried whey.

The effects on dried whey quality due to acidity, ash content, heat damage, and browning can vary over a broad range from minimal to extensive. The effect on calf performance may be subtle to very marked. This makes it extremely difficult to set down specific parameters for the levels at which particular dried wheys may be used without materially detracting from performance. It can be stated, however, that best results will be obtained with the best quality dried whey. Since high nutritional quality is demanded for animal feed applications, just as for human food applications, every whey processor should strive to produce the best quality possible to maximize the market potential for dried whey.

If all of the whey solids produced by the United States cheese industry are to be processed, we are faced with a potentially huge surplus in relation to currently existing markets for dried whey and products derived from whey. A great deal of research will be required to establish firm and profitable markets for total utilization of our whey solids. For quite some time to come, I believe, it will be necessary to look to the vast American animal feed industry as a major market for dried whey and whey products. Therefore, it is vital that we try to strengthen other feed applications where dried whey is used to some extent such as calf starter and other ruminant feeds to be discussed in the following presentations. It will be necessary to search for new bases for whey usage such as has been done in recouping some of the market for dried whey in poultry feeds by demonstrating the effectiveness of whey as a pellet binder.

Regardless of what avenues are taken in tackling the problem of whey utilization, it is imperative to keep sight of the fact that we are, in the main, seeking markets for lactose which is predominantly what we have to sell.

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Protecting Whey From Ruminal Degradation

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How valuable is whey in ruminant rations? A cattle feeder using a least-cost formulation would say it is worth about $3.53 per hundredweight (cwt.). Can you profitably manufacture whey for 3.53 cents per pound? Is $3.53 cwt. the true value of whey for ruminants?

Let us look at data based on two computer printouts (tables 1 and 2). In

TABLE 1.--Typical least-cost concentrate for dairy cows based on computer analysis

Ingredient	Amount (lb./ton) Range Min.	Amount (lb./ton) Range Max.	Amount (lb./ton) Used	Cost/cwt.	Cost/ton of amount used	Maximum cost/ton based on energy value
Wheat middlings, std.		800	800.0	$ 3.09	$ 24.72	$ 3.32
Hominy feed		500	500.0	3.10	15.50	3.67
Corn gluten feed		300	237.7	3.17	7.54	3.37
Distillers' dried grains		200	200.0	3.74	7.48	3.94
Molasses, cane	120	160	120.0	1.50	1.80	--
Lignosite	80	80	80.0	1.73	1.38	--
Corn, ground		200	55.0	3.00	1.65	4.51
Soybean meal (50%)		--	32.0	4.83	0.78	10.06
Limestone		--	25.2	0.50	0.13	14.11
Salt	20	20	20.0	1.43	0.29	--
Dicalcium phosphate		--	8.9	5.34	0.48	33.30
Fixed ingredients	1	1	1.0	35.20	0.35	--
Min. premix (P-7)	1	1	1.0	11.92	0.12	--
Cost of concentrate/ton					$62.22	
<u>Rejected as uneconomical</u>:						
Brewers' grains		200		3.03		2.99
Whey		40		4.86		3.53

TABLE 2.--Least-cost concentrate for dairy cows based on computer analysis with whey locked in

Ingredient	Amount (lb./ton)			Cost/cwt.	Cost/ton of amount used	Maximum cost/ton based on energy value
	Range		Used			
	Min.	Max.				
Wheat middlings, std.		800	800.0	$ 3.09	$ 24.72	$ 3.20
Hominy feed		500	500.0	3.10	15.50	3.32
Corn gluten feed		300	300.0	3.17	9.51	3.26
Brewers' grains, dried		200	153.7	3.03	4.66	3.21
Molasses, cane		160	140.6	1.50	2.11	1.90
Corn, ground		200	47.1	3.00	1.41	3.31
Whey	40	40	40.0	4.86	1.94	--
Limestone			33.0	0.50	0.17	10.96
Salt	20	20	20.0	1.43	0.29	--
Dicalcium phosphate			3.6	5.34	0.19	39.88
Fixed ingredients	1	1	1.0	35.20	0.35	--
Min. premix (P-7)	1	1	1.0	11.91	0.12	
Cost of concentrate/ton					$60.97	
Rejected as Uneconomical:						
Lignosite		80	1.73			0.75
Soybean meal (50%)			4.83			4.18
Distillers' dried grains		200	3.74			3.58

table 1 we see that the computer has rejected whey and will not use it because its price ($4.86 per cwt.) exceeds this figure of $3.53 per cwt.

On what basis was the whey rejected? Its energy value was compared with that of starch from wheat middlings and hominy feed, and that of protein from corn gluten feed and soybean meal. Does lactose have any advantage over starch in a ruminant ration? Is the quality of protein important? What about the minerals and vitamins found in whey? Should they be given some consideration?

In table 2 we see essentially the same ration with whey locked in the computer at the 2 percent level as a pellet binder. How do we place a value on the pellet-binding qualities of whey? You will note that lignosite, which was locked in as a pellet binder in the first ration, is valued at only 75 cents/cwt. from the protein-energy standpoint. Moreover, since whey is a good source of energy and protein, it allows for a further saving in developing high-energy rations, since it will permit greater usage of lower protein and energy feeds in achieving a designated nutritive level.

Does whey have other values for mature ruminants? Drs. Walter Woods and Wise Burroughs (12) found small quantities of whey (0.25 to 0.5 pound per animal per day) stimulated daily gains and improved feed efficiency (table 3). What value would you place on whey for this usage? It would surely be greater than the protein and energy value programmed in the computer.

TABLE 3.--Effect of adding whey and lactose to high-roughage cattle rations[1/]

Item	Control ration (pounds)	0.25 lb. whey added (pounds)	0.50 lb. whey added (pounds)	0.35 lb. lactose added (pounds)
Avg. weight of 16 steers per lot				
Initial	463	461	456	462
Final	568	582	577	579
Total gain	105	121	121	117
Avg. daily gain	2.02	2.33	2.32	2.25
Avg. daily feed consumption (52 days)				
Wilted silage	22.8	23.6	23.6	23.7
Ground ear corn	2.0	2.0	2.0	2.0
Supplement	0.5	0.8	1.0	0.8
Total	25.3	26.4	26.6	26.5
Feed consumed per cwt. gain	1253	1135	1143	1179

[1/] Test conducted at Western Iowa Experimental Farm, Castana, Iowa.

Let us also look at some feeding tests with dairy cattle conducted at Virginia Polytechnic Institute by Huber, Polan, and Rosser (3). In these tests, concentrates were fed containing different percentages of partially delactosed whey, ground shelled corn, and soybean meal, as follows:

Partially delactosed whey	0	10	20	30
Ground shelled corn	69.8	61.7	53.7	45.9
Soybean meal	22.1	20.1	18.1	16.0

Each concentrate also contained 5 percent dried molasses, 1.8 percent dicalcium phosphate, and 1 percent salt. The rations contained 6,600 I.U. of vitamin A and 8,800 I.U. of vitamin D_3 per kilogram of mix. Daily intake of the concentrate averaged 17.3 kilograms, while that of hay was 2.7 kilograms.

As indicated in table 4, the delactosed whey markedly improved the fat content of milk from cows on high-energy, low-roughage rations by altering the microflora. This improvement was significant even in a pasture situation when animals received liberal quantities of concentrate feed, as indicated in table 5. If the butterfat test drops in a herd, how much is whey worth in restoring the fat content of the milk? Have you been getting the true value for whey when fed to ruminant animals?

TABLE 4.--Effect of partially delactosed whey on milk fat and rumen volatile fatty acids

Item	Partially delactosed whey (percent)			
	0	10	20	30
<u>Milk fat (percent)</u>				
Standard	3.69	3.35	3.29	3.35
Whey treatment	3.01	3.33	3.45	3.50
Change	-0.68[a]	-0.02[ab]	+0.16[b]	+0.15[b]
<u>Rumen volatile fatty acids</u>				
Acetate (molar percent)	58.4[a]	54.7[a]	59.1[a]	59.4[a]
Propionate (molar percent)	26.1[a]	18.4[b]	18.6[b]	16.8[b]
Butyrate (molar percent)	15.6[a]	26.9[b]	22.9[b]	24.1[b]
Ratio acetate:propionate	2.24[c]	2.97[cd]	3.18[d]	3.55[d]
Ratio propionate:butyrate	1.70[a]	0.69[b]	0.82[b]	0.72[b]

[abcd] Values not sharing a common superscript are significantly different (ab, $P<0.01$), (cd, $P>0.05$).

TABLE 5.--Effect of partially delactosed whey on milk fat and milk yields with cows on pasture

Group	Fat (percent)			Milk (lb./day)		
	Pretreatment	Treatment	Change	Pretreatment	Treatment	Percent of Pretreatment
Whey	3.32	3.65	+0.33	45.7	39.8	87
Control	3.88	3.95	+0.08	40.9	34.3	84

What happens to whey as it enters the ruminoreticulum? The first three stomachs of a ruminant animal are often spoken of as the fermentation vat. Large numbers of microorganisms and protozoa are present in these stomachs to attack all foodstuffs that enter. Lactose is readily fermented by the microorganisms. The protein is hydrolyzed and then incorporated in the bodies of the bacteria and protozoa. Fat is also metabolized by the organisms. As these organisms are pushed into the abomasum (fourth stomach) they are killed by the acid and then digested by the animal just as we metabolize a hamburger sandwich.

If the feed that enters the fermentation vat is of poor quality, the microorganisms and protozoa upgrade the protein. However, if high-quality protein is consumed, its quality is downgraded. It has been reported that protozoan and bacterial protein have nearly equal biological values; but the true digestibility of protozoan protein was found to be 86 percent while that of bacterial protein was only 55 percent. Reed et al. (6) found the true digestibility of rumen bacteria to be 60 percent when fed to the rat as compared with 100 percent for casein (digestibility of protein is the percent of food nitrogen absorbed into the blood).

Since whey protein is of high quality, we would expect essentially 100 percent digestibility in a nonruminant animal. However, by going through a ruminant animal's fermentation vat the digestibility of this protein would be downgraded to essentially 60 percent. On the other hand, even nonprotein nitrogen would be converted to microbial protein with a 60 percent digestibility.

After careful examination of the amino acid composition of bacterial and protozoan protein and the availability of these amino acids, we can say that low-quality dietary proteins are upgraded and high-quality dietary proteins are downgraded by mature ruminants.

Moreover, as demonstrated in figure 1, there is a great loss of energy

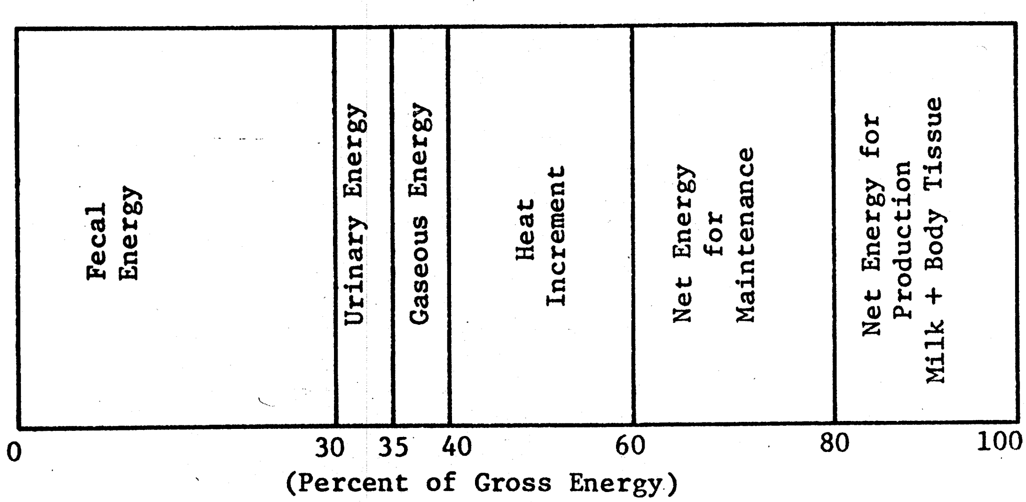

Figure 1.--Approximate percentages of the various energy components for a lactating cow.

is lactose is fermented in the rumen. The 5 percent energy from gas is a :otal loss, as well as much of the energy (20 percent) involved in the heat .ncrement of the feed.

What would happen if we continued to supply the ruminoreticulum with low-quality feed, but avoided rumen fermentation with the high-quality protein?

Reis and Schinckel (8) found the digestion coefficient of casein administered directly into the abomasum to be about 95 percent; and Reis (7) found casein placed directly into the abomasum of sheep increased the rate of wool growth up to threefold. Schelling (9) found that methionine and cystine were the limiting amino acids from microbial protein.

Many reports during the past year have dealt with effects of methionine and methionine hydroxy analog (MHA) supplementation to dairy cattle. MHA has been reported to partially resist bacterial degradation, but it is readily metabolized and serves as methionine in the biological system.

Polan et al. (5) found the milk production response curve to MHA feeding peaked at about 25 g. of MHA per cow daily; and Patton et al. (4) observed that the rumen protozoa concentration was significantly higher in lambs fed grain plus MHA than in lambs fed grain only.

Now we can see the many values of bypassing the ruminoreticulum with whey; but how can this be accomplished?

Several experiments have shown that heat treatment of protein in the presence of carbohydrates will decrease solubility and degradation.

Zelter and Leroy (13) found tannins could be used to decrease rumen degradation of peanut and soybean meal. These protein feeds were treated with tannins (13-25 percent) and then dried at a high temperature. In vitro studies demonstrated that untreated proteins were rapidly degraded by rumen microorganisms while the tannin-treated proteins escaped degradation.

Ferguson et al. (2) compared casein with formaldehyde-treated casein. Seventy-four percent of the untreated and none of the treated casein released ammonia after 6 hours of incubation in in vitro studies.

Sibbald et al. (11) reported that a dietary product consisting of methionine, kaolin, and triglycerides enveloped in a continuous film of triglycerides reduced rumen degradation and increased methionine concentration in blood plasma when fed to steers.

Other classical studies from Australia (10) have demonstrated that a mixture of oil and sodium caseinate treated with formalin (35 percent formaldehyde) was completely protected against microbial proteolysis in the rumen.

In short, evidence is accumulating to suggest that lactating or growing cattle and sheep may encounter an amino acid deficiency on rations formerly considered adequate in protein.

Whey protein is of excellent quality and will supply the necessary amino acids to assure maximum animal performance if it is protected from degradation in the ruminoreticulum. Moreover, the energy from lactose can be conserved if protected from ruminal degradation.

The potential to be derived from whey protein, if it can be thus protected, is suggested by table 6. Here the essential amino acid content of whey protein is compared, along with several other proteins, to that of the standard nutritional profile recognized to be required for optimum growth of both humans and animals by the Food and Agriculture Organization (FAO) of the United Nations. From this table it is evident that whey protein exceeds the

TABLE 6.--Essential amino acid content of whey protein, casein, and two single-cell proteins as compared with FAO standard[1]

Amino acid	Grams per 100 grams of protein				
	FAO standard	Whey protein	Casein	Single-cell proteins	
				Brewers' yeast	Experimental[2]
Methionine	4.2	4.3	3.4	1.6	1.7
Leucine	9.0	15.5	16.4	6.0	13.7
Lysine	4.2	8.2	8.2	3.4	5.8
Phenylalanine	2.8	4.0	5.5	1.8	4.8
Threonine	2.8	5.5	4.5	2.5	4.6
Valine	4.2	5.5	7.3	2.4	6.6
Tyrosine	2.8	3.7	6.2	1.9	3.8
Tryptophan	1.4	2.5	1.4	0.8	3.8

[1] Nutritional standard profile recognized by the Food and Agriculture Organization of the United Nations.

[2] Single-cell protein under experimentation by Northern Illinois Gas Co.

FAO standard in its content of all the essential amino acids. Table 6 shows the corresponding amino acid values for casein and for two single-cell proteins, brewers' yeast which is of very low nutritional quality and an experimental product of exceptionally high quality. It can be seen that the whey protein compares very well with casein and also with the high-quality single-cell protein. The whey protein is notable as the only one of the four with an adequate content of the sulfur-bearing methionine, based on the FAO standard.

Now a whey product protected from ruminal degradation is not yet ready for market. Methods of encapsulating this milk byproduct or enabling it to bypass the ruminoreticulum can be encouraged and assisted by the American Dry Milk Institute (ADMI). Then when an economical method has been developed, ADMI can unitedly work for clearance of any chemical employed in the process. The American Feed Manufacturers Association is currently engaged in such an effort for its members with respect to selenium. This type of cooperation will not only benefit ADMI members, but further strengthen and unify the organization.

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DISCUSSION

QUESTION: How did you bypass the reticulum in the work with lambs?

DR. LAMBERT: We stimulated the esophageal groove, and by this means administered the feed to the lambs as a liquid.

New Methods for Drying Acid Whey

Sweet whey has been dried successfully for years and the methods currently used in its production were ably described by Mr. Young of Kraftco during our last conference (13). However, at that time, he acknowledged that "Cottage cheese whey falls into a class of its own" and that different techniques must be developed to dehydrate it. Some of the most recent innovations in spray drying have been directed towards this end.

Most prospective manufacturers visualize the conversion of acid whey to powders that flow freely, disperse easily, have a good flavor, and are capable of maintaining these properties through extended storage. Research and experience have demonstrated that these goals can be achieved by reducing to a minimum the hygroscopicity of the powder and its content of denatured protein. Hygroscopicity can be reduced by extensive conversion of lactose to its crystalline α-hydrate form during processing. Denaturation can be prevented by reduction of the thermal stress the whey proteins are subjected to during powder manufacture. Therefore, a successful whey drying development program needs recourse to methods for measuring the flow, hygroscopicity, lactose crystallinity, and denatured protein content of dried products. The methods now available have many shortcomings at their best.

In our research we attempted to measure flow properties of powders by observing their angle of repose (2). This proved relatively unsatisfactory since, with the onset of "caking," angle measurements became impossible and the strength of the caked product could be only subjectively evaluated.

The hygroscopicity of experimental powders was determined by gravimetrically measuring the amount of water taken up by powder samples held in atmospheres of controlled relative humidity. The technique used (3) provided both equilibrium and kinetic data of high accuracy, but it cannot be considered appropriate for use during plant operations.

Polarimetry, as described by Sharp and Doob (11), was routinely used in our laboratory to determine the crystalline lactose content of concentrated wheys and powders. There is no faulting the accuracy of the method or the value of the data so obtained, but it requires the use of relatively expensive equipment and a single analysis requires data acquisition for 24 hours.

The extent of protein denaturation incurred by processing whey can be measured by determining the amount of protein in the system that is insoluble at its isoelectric point. Since whey contains a mixture of proteins having slightly different isoelectric points, some quibble exists among investigators as to how the measurement should be made. We have been unable to notice any significant difference in results obtained by adjusting the pH to any value between 4.7 and 5.1. More important is the accounting for the presence of nonprotein nitrogen that is present in wheys in relatively large amounts (4). Accurate determination of the denatured protein in fluid whey and whey concentrates and powder demands the use of some fractionation scheme (10).

The methods described allow the characterization of change that occurs in the principal whey constituents during drying. Processing steps may then be modified to achieve desired product characteristics. Whey drying generally entails (a) preheating, (b) concentration, (c) precrystallization, (d) spray drying, (e) after-crystallization, (f) fluid bed drying, (g) pneumatic cooling, and (h) fluid-bed cooling. The number of steps and the exact sequence employed varies somewhat with the manufacturers.

The preheating step can be utilized to assure a high level of denatured protein in the finished powder. The exact time and temperature of heating required to achieve a desired level of denaturation is dependent upon the pH of the whey being processed. Figure 1 demonstrates the relatively high resistance of cottage cheese whey to thermal denaturation (5). It may be worth noting that thermal denaturation of whey protein can also occur during the evaporation step that follows preheating. This is especially true when poorly designed triple-effect evaporators are used.

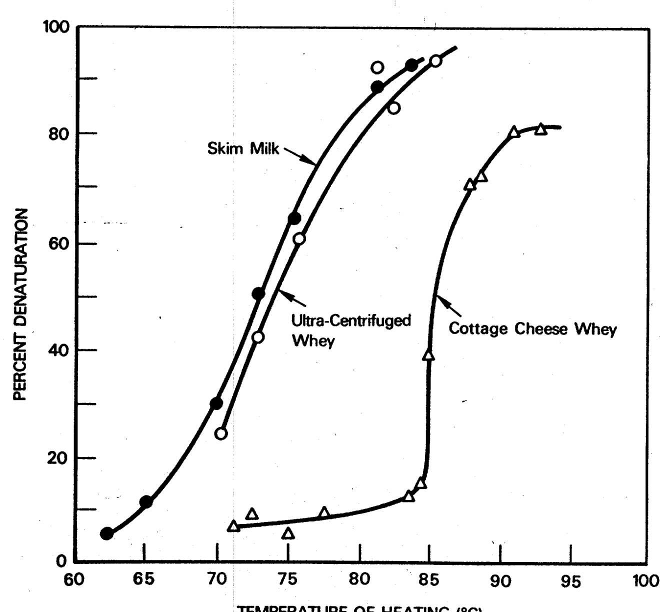

Figure 1.--Denaturation of proteins after 30 minutes' heating.

It is economically desirable to remove as much water from whey as possible during the evaporation steps. The limits to which this can be done are defined by the changing physical properties of the whey concentrate on water removal. The data presented in figure 2 show a rapid increase in the viscosity of cottage cheese whey concentrates as their total solids content rises above 40 percent (1). This initial viscosity increases on holding, as can be seen in figure 3. Cottage cheese whey concentrates containing more than

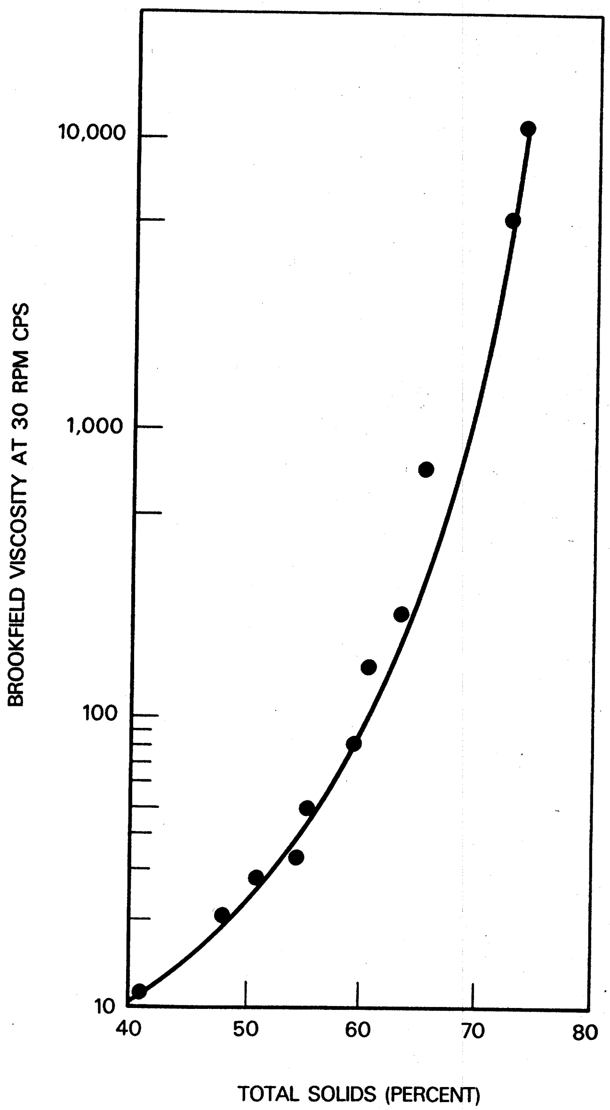

Figure 2.--Initial viscosity of cottage cheese whey at different concentrations.

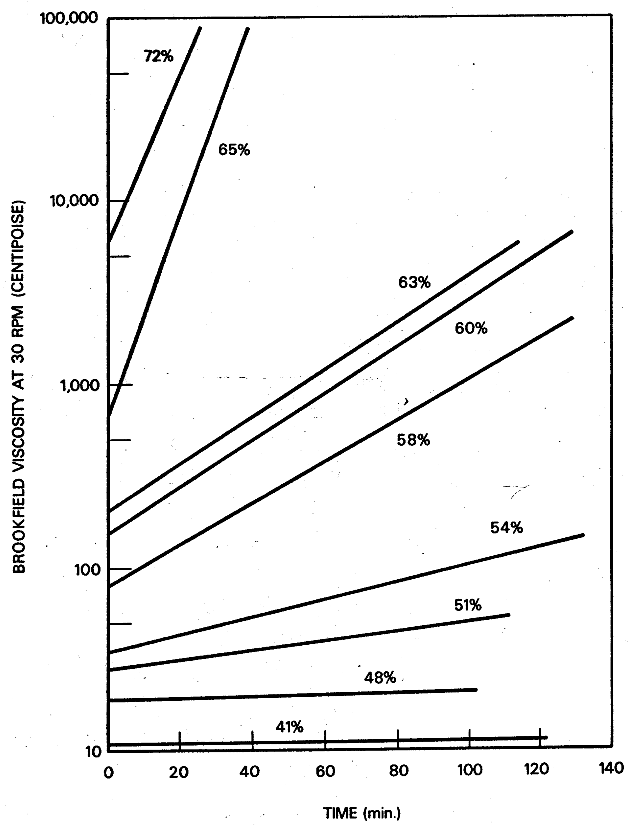

Figure 3.--Effect of total solids content on the viscosity of cottage cheese whey concentrates allowed to stand at 30-40° C.

63 percent total solids became too viscous to pump after less than 1 hour of holding at temperatures ranging from 30 to 40° C. This rapid buildup of viscosity can be reduced by stirring the concentrate. The concentrates can be considered pseudothixotropic, and their viscosities change with stirring rate, as shown by figure 4. These data indicate that vigorous stirring can be used to prevent excessive viscosity buildup in highly concentrated wheys when holding is necessary during processing (1).

Concentrated wheys are sometimes held prior to spray drying to allow

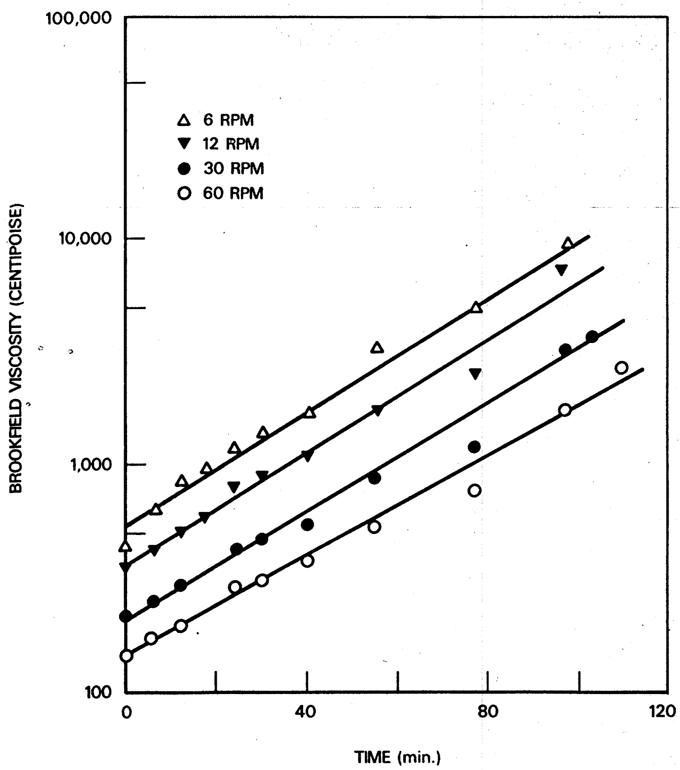

Figure 4.--Effect of stirring at different rates on the increase in viscosity with time of cottage cheese whey concentrates at 63 percent total solids and 38° C.

their lactose to be converted to the crystalline α-hydrate form. The rapid drying of whey concentrates without precrystallization results in the production of powders containing lactose in the form of a glass. This lactose glass absorbs water readily, thereby initiating the powder-caking phenomenon. Noncaking, nonhygroscopic whey powders can then be made by those methods which achieve conversion of whey lactose to the crystalline α-hydrate form.

The crystallization of lactose has been subjected to considerable study, but mostly in model systems. More work is needed to fully characterize the factors influencing the crystallization of lactose in whey concentrates. Regardless, it is known that the lactose is present in whey in two molecular forms designated α- and β-. The equilibrium ratio of β-lactose/α-lactose in whey is approximately 1.68. This ratio decreases slightly with rising temperature and is not influenced by pH (8).

When whey is held at temperatures below 93.5° C. and concentrated, α-lactose crystallizes out in the hydrate form when its solubility limit is exceeded. Mutarotation of the β-lactose maintains the equilibrium ratio as crystallization proceeds. The mutarotation rate can influence crystallization kinetics and it is known to change with temperature, acidity, and concentration of salts. It is doubtful that mutarotation is the limiting step in crystallizing α-lactose hydrate out of whey concentrates.

The extent to which the lactose in whey crystallizes as the α-hydrate and the rate at which it does so is controlled by the extent to which the solubility limit is exceeded or the system is "supersaturated" with lactose. Nuclei around which crystals form are developed in saturated solutions.

A general equation that expresses the rate of nuclei formation in terms of saturation of the solution is

$$\frac{dn}{dt} = k\,\frac{C - C_s}{C_s}$$

where n = number of nuclei

t = time
C = concentration of solute
C_s = saturation concentration of solute

When C is only slightly larger than C_s, the system is metastable. However, when C is much larger than C_s, the rate of nuclei formation is high and the crystals rapidly form in large numbers in the unstable system (7).

Rate of crystal growth around the nuclei in a supersaturated system can be equated in the general form

$$\frac{dm}{dt} = \frac{D}{L}(C-C_s)$$

where m = crystal mass
t = time
C = concentration of solute
C_s = saturation concentration of solute
D = diffusion coefficient of solute
L = depth of unstirred layer of solution at crystal face (7)

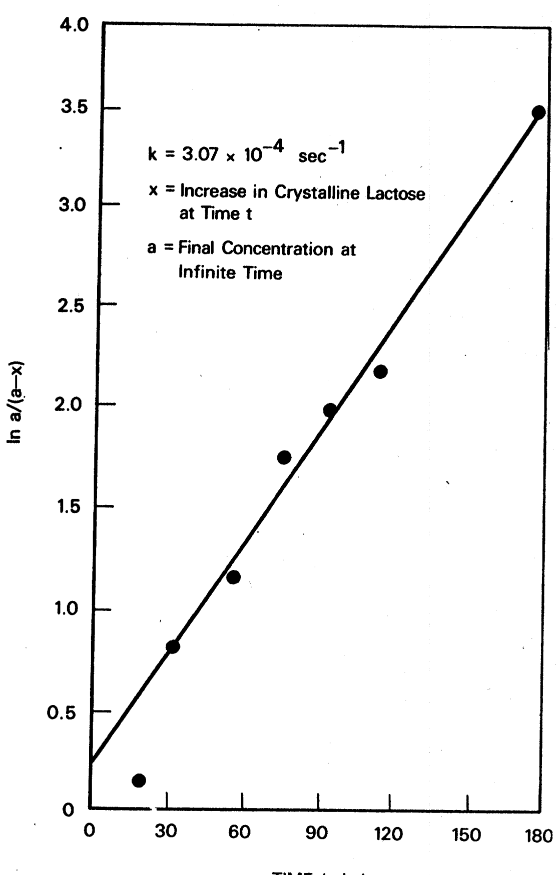

Figure 5.--Kinetics of lactose crystallization in acid whey concentrate (69 percent total solids, 40° C.).

The presence of the diffusion coefficient of the solute in the above equation shows that the viscosity and temperature of whey concentrates will also influence the rate at which the lactose will crystallize.

A consideration of the phenomena described in the general equations allows the production of satisfactory nonhygroscopic powders by allowing the crystallization of lactose to occur in concentrates high in total solids before spray drying. Crystallization can be speeded up and viscosities held down by vigorous stirring during the holding period.

The crystallization of lactose out of concentrated whey solutions apparently follows the law of first-order kinetics as demonstrated by the data presented in figure 5 (1). From the slope of the line, the rate constant can be determined. In this example 70 percent of the lactose present in an acid whey concentrate containing 69 percent total solids crystallized in the α-hydrate form during 20 minutes of holding. This is rather rapid, but it must be remembered that this change

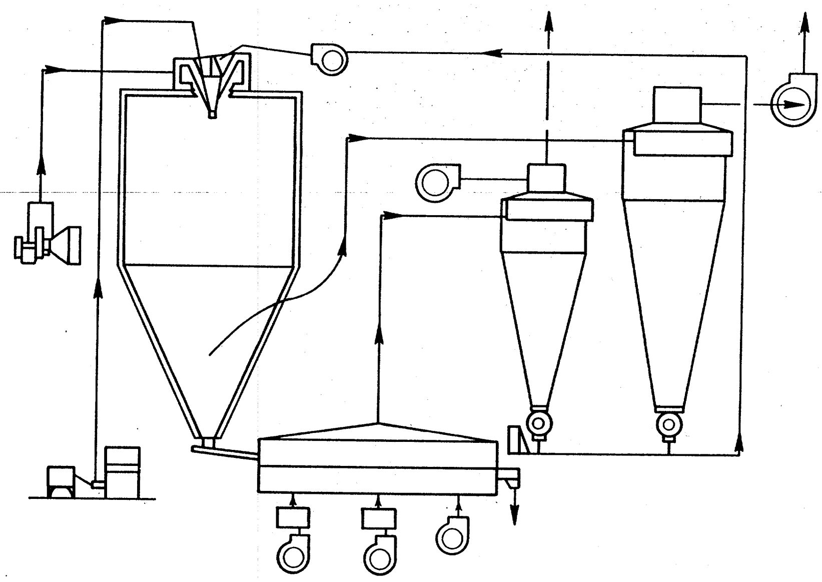

Figure 6.--Commercial acid whey drying system (Niro).

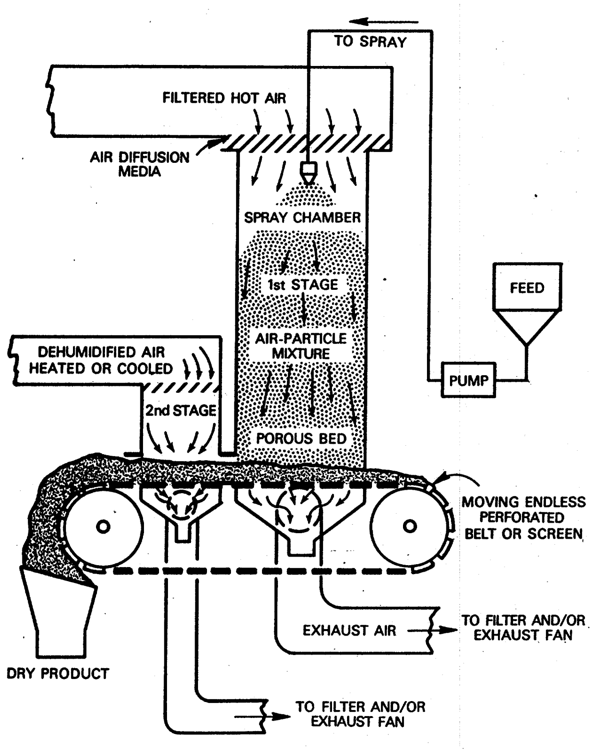

Figure 7.--Pillsbury dryer.

in state is accompanied by a rapid increase in the viscosity of the concentrate. To circumvent this problem, the newest spray driers being tested for the drying of cottage cheese whey all carry out the major part of lactose crystallization after spray drying.

Spray drying in this equipment is so controlled that sufficient moisture remains in the powder to allow lactose crystallization to continue in the damp powder mass. When crystallization has proceeded to the desired point, the residual moisture in the powder is removed in a secondary drying system. Powder quality may be improved by cooling the product before packaging. A Niro acid whey drying system capable of executing these operations is shown in figure 6 (9). A partially crystallized concentrate is sprayed into the conical drying chamber by centrifugal force. The partially dried powder is collected and fed into a fluidized bed system where the lactose is crystallized and the whey is dried, and then cooled, in sequential steps.

A dryer of more novel design that was developed by Reginald Meade, of the Pillsbury Company, is shown in figure 7 (13). In this dryer, the product builds up a mat on a porous metal belt. The product mat actually serves as a filter for the exhaust air. Being porous, the mat can be moved into other sections of the dryer for holding, further drying, and cooling. A large, more sophisticated version of the pilot model shown here is in commercial operation and has the demonstrated ability to dry cottage cheese whey.

Other interesting equipment for the dehydration of cottage cheese whey is being put into operation by Dairy Research and Development Corp. The equipment, designed by DeLaval, allows partially dried whey powder to coat the inner wall of the drying chamber from which position it falls when the crystalline lactose content of the powder becomes high. The collected powder is subjected to final drying and cooling in a pneumatic transport system.

The DeLaval system utilizes the characteristic stickiness of acid whey powders. However, the sticking of acid whey powders onto hot metal surfaces is usually a problem, and we have attempted to devise a method to study the factors responsible for this phenomenon. Figure 8 presents our Mark I Stickometer designed for this purpose. It is simply made from parts taken from glass homogenizers of different sizes. The outer stator wall is heated electrically and its temperature recorded automatically. The inner rotor is driven by an electric motor whose power draw can be recorded. The powder to be studied is placed in the annular space between the rotor and stator and the rotor is turned as the temperature of the stator wall is raised. A rapid rise in current flow into the rotor drive motor signifies the approach of the "sticking point" or the temperature at which the powder particles seize onto the receptacle walls and onto each other.

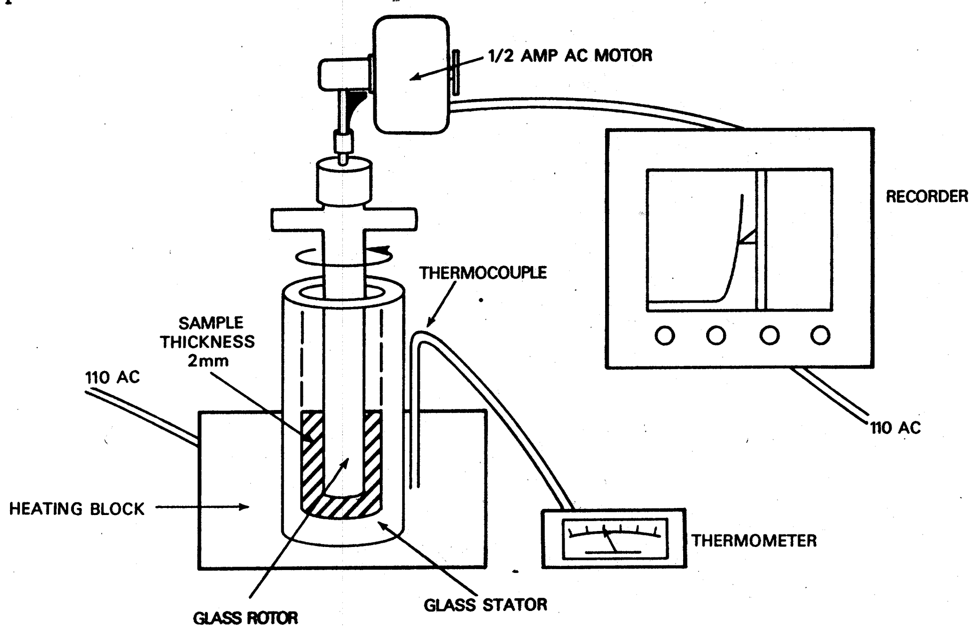

Figure 8.--Stickometer.

Data obtained by use of the stickometer are shown in figure 9. From this it can be seen that temperatures at which acid whey powders, having the same moisture content, will stick to surfaces, drops with the increasing conversion

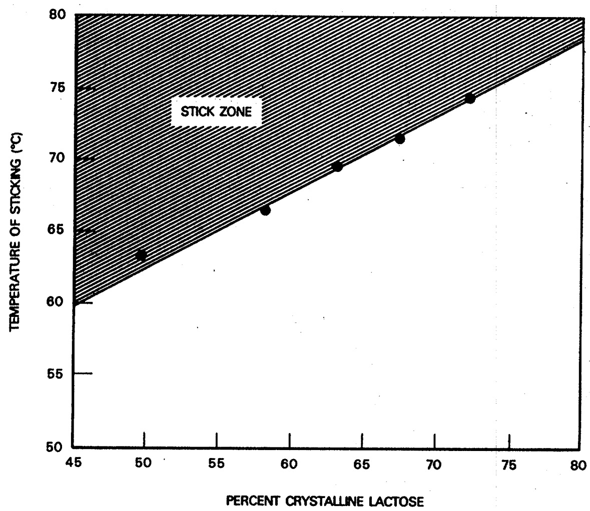

Figure 9.--Effect of crystalline lactose on the sticking temperature of acid whey powders of the same moisture content.

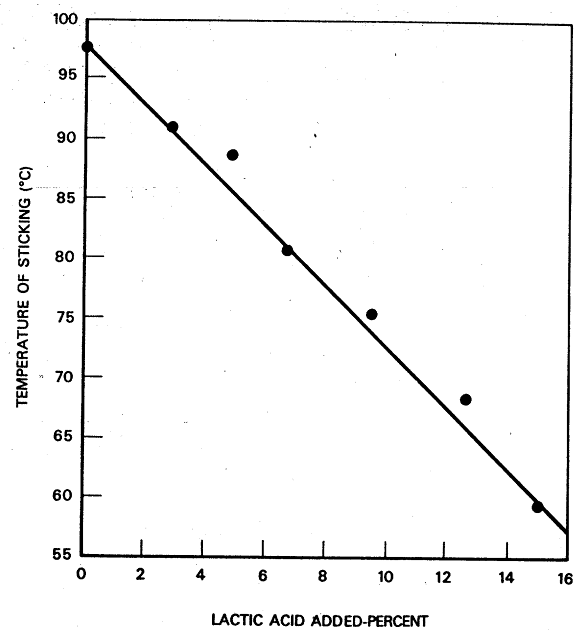

Figure 10.--Effect of added lactic acid on the sticking temperature of sweet whey powder (moisture content: 1.5 to 3.5 percent).

of the lactose present to the α-hydrate form. Therefore, it is not unreasonable to expect that the crystallization of lactose can proceed in damp powders to a point where they will no longer stick to the metal surfaces of drying equipment.

The sticking point temperature is also a function of lactic acid concentration in the whey powder, as shown in figure 10. These data readily explain why partial or complete neutralization of acid whey can reduce internal sticking of acid whey powder in drying equipment.

We have been fortunate in receiving a relatively large number of acid whey powders for evaluation during the course of our investigation of factors influencing whey drying. These originated from Dairy Research and Development Corp., DeLaval, Kraftco, Niro, and Pillsbury. Some of the data obtained by us is shown in table 1 without reference to source. Certainly a wide

TABLE 1.--Analysis of commercial and experimental acid whey powders

Sample	Moisture (percent)	Crystalline lactose (percent)	Denatured protein (percent)
A	--	11.7	86.1
B	--	57.7	86.1
C	3.65	66.8	54.2
D	1.72	77.5	33.0
E	1.96	72.4	84.2
F	4.92	78.8	81.6
G	3.58	77.6	29.5

variance in some important product qualities has been observed in the material produced outside of our laboratory. Dairy Products Laboratory research has also been directed towards the development of acid whey drying techniques that could utilize equipment we had on hand. Our goal was to effect simple conversion of existing milk drying capacity to acid whey drying. Groundwork for this was laid by the work in which Hanrahan and Webb used a foam drying system, developed to dry whole milk, to produce acid whey powder (6). The somewhat idealized plant layout is shown in figure 11.

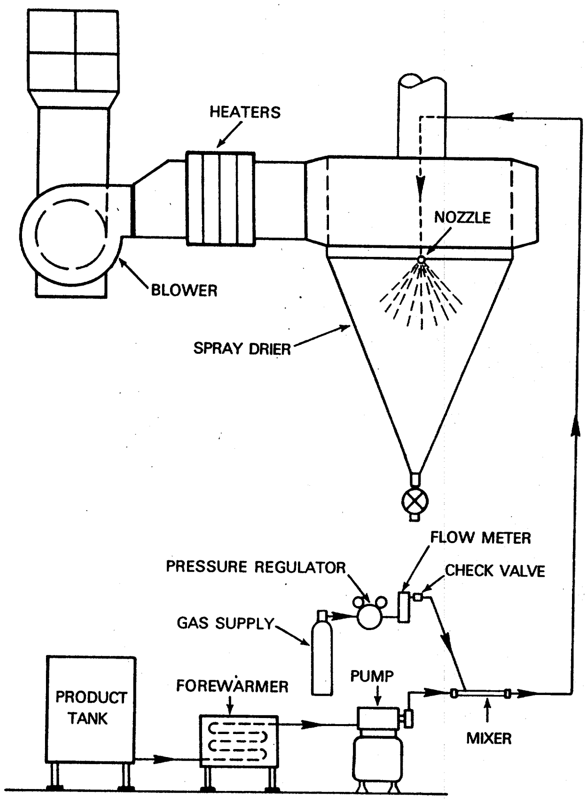

Figure 11.--Equipment for foam-spray drying of whey by gas injection.

The general scheme for foam spray drying acid whey that we now recommend is as follows (12):

COTTAGE CHEESE WHEY

↓ Vacuum concentration

52 percent total solids

↓ Cool
Hold at 20° C., 18 hr. with stirring

Crystal-containing concentrate

↓ Foam-spray dry

POWDER

(70 percent crystalline lactose)

The total solids content of the concentrate is critical, since higher solids become too viscous to pump after holding and lower solids result in insufficient lactose crystallization. Quick cooling of the concentrate and agitation during holding will result in a fine grained suspension of crystalline lactose which is easily dried by use of compressed air in the atomizer feed line. Foam-spray-dried acid whey powders have a low bulk density and mechanical crushing before packaging is desirable. Crushed, foam-spray-dried cottage whey produced in our pilot plant has the following characteristics.

Bulk density: 40 grams per liter (loose)
62 grams per liter (tamped)
Percent lactose in crystalline form: 70.2
Percent protein denatured: 5.0
Solubility index: 1.1

To summarize, research underway and commercial developments to date tend to establish that acid whey is a dryable and desirable commodity. On this premise, plants are now being constructed and operated. Any processors having trouble drying acid whey, or any who would like to have their samples evaluated, should contact us at the Dairy Products Laboratory in Washington. We will, within reasonable limits, work with you and help develop information that should be of value to both of us.

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Membrane Processing of Cottage Cheese Whey

Crowley–EPA Industrial Demonstration Grant

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Physical straining processes are defined as those processes containing elements which remove solids by virtue of physical restrictions at their surfaces, and which have no appreciable thickness in the direction of liquid flow. Among the processes which fit this category are rotary screens, vibrating screens, diatomaceous earth, and ultrafiltration.

Microscreening has been a viable process more than 20 years. The Luton Sewage Works in England used microscreening as a tertiary waste treatment back in the early 1950's.

Basically we can conclude that all membrane processing systems will share certain common operating and design characteristics. Dissolved materials are separated from water through "fine" membranes with reasonably high driving forces of pressure of several hundred pounds per square inch (p.s.i.). Particles in colloidal stage, suspended materials, and large macromolecules can be captured from waters through "coarse" membranes at low 10-100 p.s.i. driving force pressures from 10 to 100 p.s.i.

In the removal of salts or solids, membrane fouling tends to cause the flux or permeate to decline logarithmically with time.

Membrane types and their geometrical configuration are important to microscreening performance. Leading manufacturers of membrane systems are Abcor, Amicon, Dorr-Oliver, and others.

The single greatest problem of ultrafiltration is membrane fouling which causes membrane flux to decline. This is frequently mentioned in the literature; for example, in the process design manual for suspended solids removal for E.P.A. technology transfer by Burns and Roe, Inc. (Contract 14-12-930). Such fouling is caused by slimes, precipitates, and microbial deposits. Membranes can be cleaned routinely with chemical or enzyme solutions but fouling prevention is a design problem.

The flowing of feed water and solutions past membrane surface serves to constantly scour or sweep the filter surface, thereby discouraging fouling.

With these opening remarks, I can report that the Crowley-EPA Phase II Ultrafiltration-Reverse Osmosis Plant at LaFargeville, N. Y., has been operational since last May 15.

Data generated in Phase I pilot work were scaled up by an approximate 15-fold design factor to the present plant.

Anticipated flux rates (or pounds-per-hour capacity) have been achieved. In fact, scale-up criteria appear to be linear functions for flux and performance as suggested by experience from bench to pilot plant and now onto industrial design.

Current problems are but three, and in the following order of importance:

1. The equipment supplier experienced quality problems with a number of reverse osmosis (RO) membranes inserted into membrane modules. Only four ultrafiltration (UF) membrane tubes showed an adhesive problem evident by a failure in holding plastic ferrules in place. These malfunctions along with some special bolts are to the best of our knowledge now replaced or corrected.

2. We may have over-designed the system for flexibility, thereby making the day-to-day operation of the plant more complex than it needs to be.

3. On-site water quality can present troublesome conditions for membranes. Certain water contaminants must be recognized early so that any necessary water treatment can be incorporated in the plans. At LaFargeville our people did come to grips with high dissolved solids in raw water and prepared reasonable solutions that will hopefully sidestep the problems they could create.

As you know, there is at this time little or no industrial expertise in whey processing using membranes. The Crowley design is both flexible and expandable. Perhaps others in the evolutionary progress of the process can elect to construct simple, straight-forward plants with flows better than our demonstration grant design. For example, we find that six-inch stainless welded lines with CIP circuits are somewhat cumbersome. In addition, we also recognize that stand-by equipment represents a sizeable dollar investment. But with uncharted courses the risk of failure must be reduced with adequate provisions against potential lost-time situations.

In order to appreciate the 300,000 pound-per-day whey plant, we might wish to briefly reacquaint ourselves with the Phase I pilot work in Binghamton, N. Y.

Figure 1 describes the industrial plant that is now operational in LaFargeville.

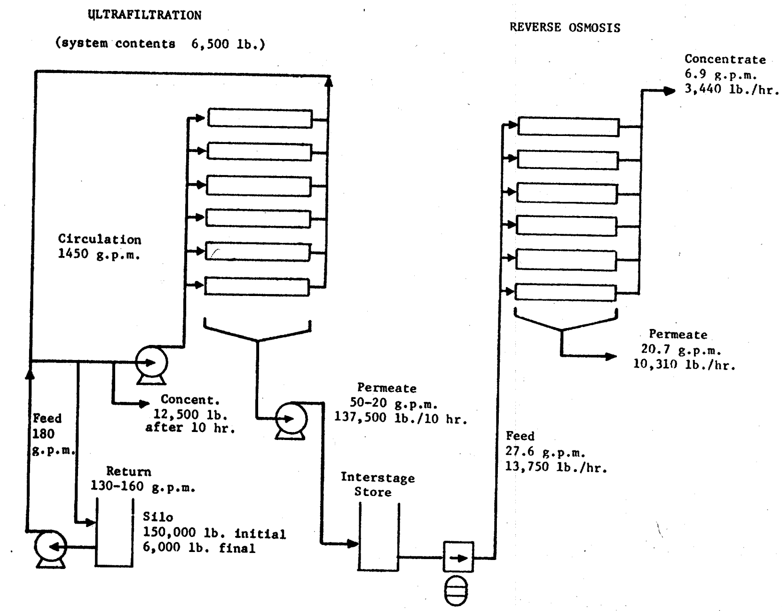

Figure 1.--Design conditions for Crowley-EPA phase II ultrafiltration-reverse osmosis plant at LaFargeville, N. Y.

In the membrane separation processes for whey, the membranes used are thin films of organic materials. They are so manufactured that water in a solution will pass through them under pressure. Some, but not all, of the compounds in the solution permeate the membranes. In fact, various molecules in solution pass through the membranes in varying proportions. Membranes filter the molecules in such a manner to concentrate them in solution. In reverse osmosis, most of the molecules are so filtered; in ultrafiltration, only the largest ones are, such as the proteins.

Because membranes are thin and have little strength they are almost always supported. In our plant the membranes are inside porous tubes which are held against supports by pressure. A porous tube with its membrane is referred to as a membrane tube. Two types of filters are used in this whey processing plant, ultrafiltration membrane tubes and reverse osmosis membrane tubes.

Ultrafiltration membrane tubes operate at a maximum of 50 pounds per square inch gage (p.s.i.g.). They are connected together with plastic piping, and require no additional fittings. Reverse osmosis membrane tubes have smaller pore size and operate at 900 p.s.i.g. These films are glued firmly into stainless steel castings. Twenty reverse osmosis membrane tubes are assembled as a group in stainless steel connectors and the nest is referred to as a membrane unit. Blocks of membranes have been combined in sections to form building units.

An Abcor UF-480S module (an ultrafiltration module with 480 square feet of membranes) is a stainless steel cabinet containing 216 ultrafiltration membrane tubes with all the necessary piping and cleaning sprays. The RO-850S (a reverse osmosis module with 850 square feet of membranes) is a stainless steel cabinet containing 63 reverse osmosis units together with all the necessary piping and cleaning sprays. In this plant there are six UF-480S modules and six RO-850S modules.

Ultrafiltration membranes are designed to retain only large molecules and to permit water and small molecules to pass through them. The solution which passes through a membrane is referred to as permeate. The solution which does not pass through the membrane is referred to as concentrate. During a batch run of 150,000 pounds of whey, 137,500 pounds (11/12ths of the whey) will pass through the ultrafiltration membrane. Protein is accumulated in the concentrate, and at the end of the run will be present at about 7.2 percent. The smaller molecules in whey (lactose and salts) pass through the membrane. Thus at the end of the run they are present in both the concentrate and in the permeate at approximately their original concentration in the whey.

Ultrafiltration permeate feeds the reverse osmosis section. Reverse osmosis membranes are supposed to retain all molecules and to pass only water. In fact they retain more than 97 percent of the salts and a still higher percentage of the lactose and lactic acid molecules. In this section of the plant three-quarters of the feed will permeate. The concentrate leaving the plant will contain about 4 percent salts and between 16 and 20 percent lactose and lactic acid. The permeate discharge contains about 0.07 percent salt with small amounts of lactose and lactic acid which shows up as a positive biological oxygen demand (BOD). The quantities of dissolved solids in the permeate is a fixed fraction of the dissolved solids in the concentrate. Thus the more concentrated the lactose stream, the higher will solids appear in the permeate.

The rate at which solution permeates membranes is called the flux or flux rate. Flux is usually reported in gallons per square foot per 24-hour day (g.f.d.). [To use these units in the ultrafiltration section, remember that each module contains 480 square feet so that a flux of 1 g.f.d. is equivalent to a permeate flow of 0.333 gallon per minute (g.p.m.). In a reverse osmosis module, which contains 850 square feet, a flux of 1 g.f.d. produces a permeate flow of 0.591 g.p.m.]

The Ultrafiltration Process

Operating conditions.--In order to obtain the best continuous flux rate, certain conditions are desirable. Operating temperature should be as high as possible without degrading or hurting the membranes, which in ultrafiltration is between 120 and 125° F. UF pressure should be held between 15 to 50 p.s.i.g. with turbulent whey kept moving inside the membrane tubes. Because flux rate decreases when the concentration increases, the protein concentration is kept as low as possible for the longest possible period of time in a batch run.

UF whey is kept moving by two large circulation pumps in the plant; one for stand-by and one for operation. These pumps deliver between 1,400 and 1,500 g.p.m. The rapid flow of whey through the membrane tubes demands a large drop in pressure. Therefore, to maintain flux, pressure is set not to go below 15 p.s.i.g. To protect the membrane tubes, the pressure is regulated so as not to exceed 50 p.s.i.g. An allowable pressure drop approximates 35 p.s.i.g. and is obtained when whey flows through 18 membrane tubes in series via manifolds through 12 parallel sets.

Control of concentration.--Now consider the need to keep the concentration as low as possible in the circulating loop inside the membrane tubes. As liquid permeates, more liquid must be supplied to the circulating loop in order to maintain the pressure. There are two feed pumps in the plant, but only one is normally used at a time, while the other is being cleaned or is available for stand-by operation. The pump feeds whey from the storage silo into the circulating loop to make up for the permeation. However, the total permeation rate of whey from this part of the plant is between 20 and 50 g.p.m., and the feed pump is designed to supply 180 g.p.m. The surplus liquid from the feed pump leaves the circulating loop through a valve (30U) and is returned to the storage silo. The minimum pressure in the circulating loop (15 p.s.i.g.) is maintained by the pressure drop of the liquid through valve 30U and is controlled by throttling this valve. The high rate of flow back to the storage silo insures that both the contents of the silo and the contents of the circulating loop become concentrated at the same time. If we did not return any liquid to the storage silo, the concentration in the circulating loop would rapidly become high and for the remainder of the run we would be permeating from a high concentration. By mixing back into the silo we delay, until the end of the run, the time when the concentration reaches its maximum. The operation of the ultrafiltration section is a batch operation. The silo is filled with 150,000 pounds of whey, the circulating loop is filled, and circulation is started. As permeation proceeds, the concentration in both the silo and in the circulating loop increases and the level of liquid in the silo falls. The plant is designed so that at the end of ten hours 137,500 pounds of liquid will have permeated and 12,500 pounds of concentrate will remain inside the circulating loop and in the silo. The level in the silo will be between one and two feet at the end of the run. The run is continued until the concentration in the concentrate is as required; that is, until the level in the silo drops to the predetermined point. When the run is over, the concentrate must be recovered both from the silo and from inside the membranes and piping and pumped to concentrate storage. When the first run is over the inside of the membranes will be quickly cleaned and a second run will begin. When the concentrate from the second run is recovered, the plant should be thoroughly cleaned and sanitized before starting again. The plant is designed to concentrate two batches, each having 150,000 pounds of whey, in 20 hours, leaving four hours for cleaning up.

Removing the concentrate and cleanup.--Three different methods are used to remove the concentrate from inside the system. The concentrate left inside the silo is pumped out with a feed pump. The concentrate left inside the large, overhead headers is drained out of the system under gravity. The concentrate left inside the membrane tubes in the module is pushed out of the system with water. This pushing, displacement procedure can and must be used to recover concentrate from the small-diameter membrane tubes; it is not used to recover concentrate from the 6-inch diameter headers because the displacing fluid and displaced fluid will undergo too much mixing in pipes of such a large diameter.

As soon as the concentrate has been recovered, the system is flushed and cleaned. One should avoid leaving the plant in a dirty condition. Even for a short hold-up period of a couple of hours, it is best to flush the system by pumping water through the modules in series, as in recovering the concentrate.

Cleaning the UF membrane tubes is most effective when there is minimum solution permeation of the cleaning solution. Suspended soils should be in the moving stream of the cleaning solution and not be allowed to be swept back onto the membrane by a high permeating flow.

Checking the permeation rate.--Permeation is the vital objective of the plant. Measuring the rate of permeation is, therefore, most important for monitoring operational efficiency. A flowmeter in the transfer line meters deproteinized whey to the interstage silo. This flowmeter should be read frequently and graphed to indicate the progress of the run. Inspection of the product's turbidity gives a quick indication of the quality of permeation. Permeate samples obtained at an interstage balance tank is regularly and frequently inspected by a fast boiling method. If the turbidity exceeds a tolerable limit, then the operator is warned immediately to look for the leak and remedy the situation.

Flexibility of plant.--We have attempted to construct a flexible chemical plant. For example, if one or any number of the modules are not to be used, they can be put into stand-by. By closing appropriate block valves, and opening module vent valves, a small amount of filtered water can flow slowly through stored modules. Membranes are indeed perfect filters and as such they trap dirt carried in with the storage water. For this reason, a vent valve is opened and water is permitted to discharge continuously through the system to a sewer rather than deadending within the system. This action might be analagous to blowing down a boiler for obvious reasons. The modules on standby are best cleaned and sanitized once every three days. This is done to avoid molds which can be carried in water.

The RO Process

Operating conditions.--Like the ultrafiltration, this section of the whey plant contains six modules so arranged that the feed solution, which is the UF permeate, is fed to the modules in parallel. Unlike a batch operation, the solution passes once through the modules and its concentrate discharges continuously. Each module contains 63 RO units, each having 13.5 square feet, building the module to 850 square feet. The 63 units are arranged in 21 sets of three units through which liquid flows in series. Manifolds distribute the feed solution so that the flow path is: 9 parallel sets, followed by 5 parallel sets, followed by 4 parallel sets, followed by 3 parallel sets. As solution permeates out, the number of parallel flow paths is decreased so that the linear velocity of the concentrate inside the membrane tubes is maintained.

The RO membranes in this plant are supposed to hold back all solute molecules and to pass only water. The lactose concentrate exhibits high osmotic pressure (approaching 400 p.s.i. for the exit); thus pressures this high must be used inside the membrane tubes, both to overcome the osmotic pressure and to overcome membrane resistance. Permeation rate is used approximately linearly as the primary flow control in this section. However, during operation the pressure must not drop below the osmotic pressure. If the plant is too big for the job, then the membrane area can and must be decreased. As in UF, one or more of the RO modules can be removed from service. Pressure above 800 p.s.i. is avoided because of possible damage to these membranes.

The high pressures needed for RO processing is provided by sanitary homogenizer pumps. There are two, but one is for stand-by. The plant is designed to process 13,750 pounds per hour of feed (27.6 g.p.m.), of which three-fourths permeates (20.7 g.p.m.) and one-fourth leaves as concentrate (6.9 g.p.m.).

Controlling the flow rate.--The fixed flow capacity of the pumps is 36 g.p.m. This is more than the design feed rate, so a small flow of solution is at all times bypassed around the pump through a throttling valve. The system feed rate can be read on the flowmeter mounted on a panel next to the pumps. The feed rate is controlled by an adjusting valve. If one of the modules is not in use, then the control valve must be opened to lower the feed rate to the system. The rate of flow of concentrate can be read on the concentrate flowmeter. To obtain the design concentration, the pressure is adjusted so that the concentrate flow rate is one-quarter of the feed flow rate. The pressure is controlled by letting the concentrate leaving the system flow through a spring-loaded back-pressure regulator. This regulator must be adjusted to obtain the design concentration, provided only that the pressure is not allowed to exceed the limits already mentioned. The flow of solution through the RO units causes a pressure drop of about 200 p.s.i. so the inlet and outlet pressures are not the same.

Other operational controls.--Unlike UF, RO membranes are inserted, not cast on a carrier. As such they are more sensitive to temperature, which should not exceed 90° F. at the membranes. Similar to milk plants, the pressure at the suction side of the pumps should not be subatmospheric to avoid injury to the fragile membranes. To control both the temperature and pressure, a booster pump is used to force feed from the interstage store through a heat exchanger where it is cooled before reaching the high-pressure pumps.

Let me state again that it is most important that none of the membranes, especially the expensive RO membranes, should be allowed to dry out. A check valve at the entrance to each module will pass water into a module whenever the pressure in the module goes below about 5 p.s.i.g. A special pressurized water tank in the water line connects to all the check valves. The pressure in this tank is kept above 15 p.s.i. at all times.

Many operational controls and alarms are incorporated into the plant, but some operator still has to push the correct button.

As previously mentioned, a sign of a leak in the UF section is detected quickly by an increase in the turbidity of the permeate. Sometimes this cannot be seen in permeate if leakage is slight. The quickest way to detect a leak, however, is to check for protein coagulation by a boiling test. Since it is not very convenient to take permeate samples from individual modules, the check is usually performed on samples taken from the balance tank.

<u>Detection and replacement of leaking modules</u>.--When a leak is detected, it is necessary to locate the module and then the leaking tube. A fairly fast leak can usually be heard. A slower leak will frequently be seen as a white colored line of liquid running down the inside of a module. Most leaks occur at the ends of the tubes and can be seen by opening the end doors and examining the system. As soon as the leaking tube has been located, it should be marked, and the inlet and exit values for that module should be closed at the control panel. This puts the module out of service. It may be necessary then to adjust the system pressure, which will rise about 5 p.s.i. The PVC U-bends are removed from each end of the faulty tube by loosening the nuts. The faulty tube is removed and a new one slipped into place.

Leak detection in RO units is monitored by a continuous RO conductivity monitoring meter built into the control panel. Leaks can also be discovered by hand-measuring samples taken from the permeate line sample valve. Although cumbersome, it is quite possible for an operator to locate an RO leak by looking down between the rows of membrane tubes.

A faulty unit, which contains twenty 5-foot-long tubes, may be removed quite easily from the module by removing several screws in its upper head. If another unit is not immediately available, the space in which the faulty unit was located may be bypassed by substituting a jumper head. As soon as the unit has been replaced or jumped, the module can be put back in service by opening the exit and inlet valves slowly. Air introduced into the system is troublesome and must be driven out without causing bumping.

<u>Typical results of recent run</u>.--Recent typical results of the operation are presented as follows:

Date: June 7, 1972; single batch of 18,000 gallons or 150,000 pounds; total time: 9 1/2 hours or approximately 15,500 pounds per hour average.

Biological Data of Storage Liquid:

UF modules 1 through 6.
SPC Coli <1 and SPC <100

During operation:

Coli <1 and SPC <1,000

Permeate from RO:

BOD_5 approximates 1,000 mg./l. or $\cong$95 percent reduction from feed. This extrapolates on a full operation to 300 pounds BOD total for the entire permeate amount.

The Crowley-EPA venture and others in like demonstration programs show a new willingness on the part of corporate firms to cooperate with the industry and with this Institute. Perhaps together our whey--the misplaced resource--can be processed to provide benefits to all.

Report on USDA–H. P. Hood Contract

F. E. McDonough

Traditionally, June is the month in which school ends and those of you who have children will be receiving their report cards in the next week or two. For the USDA-H. P. Hood project, this is also report card time. The report will be incomplete, though, since the project doesn't officially end until June 30, and the final report has not been prepared.

I'd like to introduce the contract and tell you what we hoped to accomplish. It was titled "Investigations on the evaluation of commercial-scale processing of cottage cheese whey by RO/UF." As most of you know, we at the Dairy Products Laboratory were pioneers in the use of membrane separations as applied to dairy products. We have reported on both reverse osmosis (RO) concentration and ultrafiltration (UF) fractionation of whey. The reports indicated good results under ideal pilot-plant conditions, using small batches of product, operating for relatively short periods, and giving an amount of personalized attention that would be impossible on a large scale.

What happens when a system is operated daily for 10 or 20 hours? What are the engineering problems in scaling up? How much attention does the operation require? How reliable are the membranes and component parts? Can the system be adequately cleaned to restore flux daily and can it be sanitized to control microbial growth? What are the economics of the operation? These are some questions we hoped to answer in determining the feasibility and practicality of the processes.

More specifically, the contractor was to obtain equipment with both RO and UF capabilities and install it in his cottage cheese plant. The maker of the equipment was not specified, but performance guarantees were required. The performance specifications were based on results obtained during our pilot-plant work. The RO unit was expected to concentrate 30,000 pounds of whey to a 4-to-1 ratio within 20 hours, while rejecting at least 99 percent of the protein, 95 percent of the lactose, and 90 percent of the biological oxygen demand (BOD). The UF unit was expected to fractionate 30,000 pounds of whey to a 90 percent permeate reduction level within 20 hours, while rejecting at least 95 percent of the protein. A comprehensive analysis of the fractions was required including total solids (TS); lactose; ash; protein; nonprotein nitrogen; BOD; chemical oxygen demand (COD); and total counts, coliform, and yeast and mold counts.

The contract period was two years, allowing time for obtaining and installing equipment and support facilities, and time for shutdown and re-engineering as problems developed. Operation was to be on a 5-day week for a sufficient period to achieve 120 days of running time, including 100 ten-hour days and 20 twenty-hour days. Among the few manufacturers ready to guarantee to meet specifications, Abcor, Inc., of Cambridge, Mass., was low bidder. They provided the systems which were installed in the H. P. Hood cottage cheese plant in St. Albans, Vt.

A brief description of the operation follows: Cottage cheese whey was pumped from the second floor make-room to a holding tank on the first floor. The whey was then circulated through 8 banks of eighteen 1-inch UF tubes in series, totaling 320 square feet of membrane. Feed rate was 15 to 18 gallons per minute (g.p.m.), inlet pressure 45 pounds per square inch (p.s.i.), outlet pressure 15 p.s.i. The protein concentrate was returned to the holding tank and recirculated by batch procedure until a 90 percent volume reduction was obtained. The fluid permeating the membrane was pumped to a second holding tank and in most cases was fed into the RO system for concentration.

The RO system consisted of 50 modules, each containing fourteen 1/2-inch tubes enclosed in a clear plastic shroud. The tubes totaled 475 square feet. Feed rate was 3.3 g.p.m., inlet pressure 600 p.s.i., outlet pressure 400 p.s.i. Obviously attempts to pump through such a large number of tubes in continuous series would result in a large pressure drop and loss of turbulent flow. A manifold hookup that allowed staging overcame the problem nicely. Staging can best be compared to a "Christmas-tree effect" where flow first proceeds simultaneously through a large number of tubes, and then progressively feeds into a smaller number. The design worked very well; pressure drop was held to a minimum.

RESULTS

Ultrafiltration

Table 1 is fairly typical of the type of separation results obtained from the UF membranes. Note that the solids of both the feed whey and concentrate are rather low. This is because for most runs, some or all of the first wash water was included with the whey. I might mention at this point that we have Abcor's 44S pilot-plant unit at our labs in Beltsville, Md., so we have back-up data to compare with that obtained at St. Albans. If straight whey of 6.5 percent TS had been used, processing to the 90 percent level would have given a solids level of 12 to 13 percent. A 95 percent volume reduction would have given 18 to 20 percent solids. Note also that the feed contains about 8 to 9 percent protein on a dry-weight basis while the solids of the UF concentrate is 41.8 percent protein. This is consistent with results obtained at and concentrate during an actual run. About 85 percent of the protein was recovered in the concentrate even though the rejection of the membranes by calculation was over 95 percent. Note that about 90 percent of the lactose remained with the permeate. Our work at Beltsville is in good agreement, showing a slightly higher yield of 90 to 91 percent protein.

Recalling that the unit was sized to fractionate 30,000 pounds of whey to the 90 percent level in 20 hours, and that the tubes totaled 320 square feet, the flux rate would have to average 10 gallons per square foot per day (g.f.d.) to achieve the desired level. The membranes met or exceeded these specifications, often averaging 14 g.f.d.

Reverse Osmosis

Table 3 illustrates the performance of the RO membranes. As indicated

TABLE 3.--Analysis of RO fractions of whey

Fraction	Whey	Concentrate	Permeate
Total solids, percent	5.15	22.83	0.06
Protein, percent	.51	2.31	.00
Lactose, percent	3.26	14.26	.04
Ash, percent	.64	2.55	.03
Lactic acid, percent	.53	1.90	.08
BOD	59,600	-	610

earlier, this system was staged to allow concentration to a desired level in a single pass. Table 3 shows a 4.4-to-1 concentration ratio, going from 5.15 to 22.83 percent TS. The component balance in the permeate is not as accurate as it should be, but the important thing here is that we have permeate low in solids and free of protein. The BOD is reduced almost 99 percent. This was accomplished at an average flux rate of about 6 g.f.d. This is the equivalent of processing some 7.7 gallons of liquid whey per square foot to a concentration level of 4.4.

Operational Problems

The good news is, then, that the RO and UF systems work and can do the separations we expect from them. There is also some bad news, however. A number of problems were encountered, most of them minor, but two that must be

TABLE 1.--Analysis of UF fractions of whey

Fraction	Whey (percent)	Concentrate[1/] (percent)	Permeate (percent)
Total solids	5.03	9.27	4.86
Protein	.44	3.88	.07
Lactose	3.40	4.18	3.25
Ash	.61	.70	.60
Lactic acid	.47	.56	.46

[1/] 90 percent volume reduction.

Beltsville. A 50 percent protein based on dry weight could be obtained by continuing processing to a 92.5 percent volume reduction, and a 95 percent volume reduction would result in a 56 to 57 percent protein concentrate.

Mathematical formulae have been devised for determining percent rejection and retention as a means of evaluating performance of the membranes. During this project, generally over 95 percent of the protein was rejected based on these calculations. However, Walter Kneeland (project leader from Hood) and I both feel that while these formulae for evaluating performance are mathematically valid, they are misleading. One reason is that some of the protein is lost on the surface of the membrane, so that the percent rejection and the percent recovery are never the same. To illustrate, table 2 follows on a pound basis the disposition of the components of whey, permeate,

TABLE 2.--Partition by UF of components from 100 pounds of whey

Fraction	Whey (pounds)	Concentrate (pounds)	Permeate (pounds)
Water	94.86	9.06	85.80
Total solids	5.14	.94	4.20
Protein	.44	.37	.07
Lactose	3.45	.38	3.07
Ash	.61	.09	.52
Lactic acid	.42	.06	.36

mentioned: cleaning the units and sanitizing them.

Shortly after installation we became aware that the quality of our water supply was a critical consideration. Water that is high in iron or other minerals or, like the St. Albans water, high in frog legs and other debris, can clog the membranes without the help of whey protein. Installation of a filtering system removed this extraneous matter, but the water's microbial population occasionally was high enough to provide a serious source of contamination. For example, it was not unusual for the water to contain a total microbial count of 4,000 per milliliter, a coliform count of 20, and a yeast and mold count of over 1,000.

Ultrafiltration unit.--At this point I'll separate the discussion of the RO and UF units since their problems had to be handled differently. From July 8 to December 31, 1971, 89 UF runs were made. Seventeen were 20-hour runs and 72 were 10-hour runs. Approximately 77 percent of these runs met or exceeded specifications. Table 4 shows the typical microbial quality of the fractions during one of the early successful runs. These particular data were from a 20-hour run, so the counts are very impressive. The concentration factor alone would account for a tenfold increase in the count of the feed whey, so one can see that good quality products can be made when the equipment is clean and conditions are right.

TABLE 4.--Microbial quality of UF fractions[1/]

Organisms	Whey feed (number/ml.)	Concentrate (number/ml.)	Permeate (number/ml.)
Total count	400	18,600	1,000
Coliform	0	0	0
Yeast	2	4	1
Mold	1	0	0

[1/] Batch procedure; 20 hours.

After 2-1/2 months of performance like this, the flux rates became spotty, continued this way for four weeks, and then stayed below specifications. During this time the microbial counts, especially the yeast counts, got out of control. Finally a massive slime layer appeared on the exterior of the tubes. It became apparent that the slime buildup had been responsible for the loss of performance. Of the 20 below-par runs during this period, 18 were attributed to the slime buildup. One must conclude that the sanitizing procedures had not been adequate.

Now let's look at these procedures and how we altered them to correct the problem. Following operation, the UF unit was originally cleaned in place by first flushing with cold water at high flow rates and low pressure. This was followed with a 60-minute cycle of enzyme detergent at 120 degrees F. The detergent permeate water was pumped from the unit and circulated through the spray bars over the exterior of the tubes. After another rinse, the unit was shut down until the next use.

Sanitation with 100 parts per million (p.p.m.) chlorine was not done until just prior to the next run. This gave the bugs some pretty happy hours before they were exposed to chlorine.

Our error was too much concern for the surface of the membrane and not enough for the porous structure of the support tubes. The procedure was revised to greatly increase the amount of flushing through the tubes. Not only was the flush time increased, but more important, the feed rate during both flushing and enzyme cleaning was lowered and the pressure was raised. The effect was to greatly increase the flow of water through the membrane, resulting in better flushing of the substructure. In addition, enzyme detergent was sprayed over the tubes through the spray bars. Prior to this, the detergent permeate was used, but since most of the detergent is rejected by the membrane, little or none was actually getting to the exterior of the tubes. A final rinse of 120 degrees F. water also greatly increased the flow through the tube walls. Monitoring of dissolved solids from various parts of the unit indicated that the new procedures were getting the unit clean.

Sanitation was improved by chlorinating both prior to and after each use. Rather than cold water, warm water was used to increase activity and permeation of the sanitizing solution. Much work and experimentation with various chemicals removed the slime buildup and restored microbial control. Unfortunately, either the chemical treatments or the organism appeared to have damaged the membranes slightly because although the flux rates were restored, the protein rejection never fully recovered. Microbial control following these changes has been good, and we are confident that the new procedures will be effective.

Reverse osmosis unit.-- The RO system presented different problems. First, there were no spray bars in the modules and no way of using turbulence while cleaning the permeate side. Second, the RO membranes were obviously tighter with very high rejection of most solids. Whereas chlorine penetrated the UF membranes, most of it did not pass through the RO membranes. The tightness of the RO membranes also resulted in significantly lower water flux rates, and flushing the support tubes was much less effective. Third, the RO membranes have different temperature and pH tolerances. Whereas the UF membranes were not harmed by pH's as alkaline as 9 and temperatures as high as 125 degrees F., the RO membranes could not withstand pH's above 7 or temperatures above 90 to 100 degrees F.

Original treatment for the RO unit consisted of a rinse with cold water and exposure of both the shroud and inside of the tubes with enzyme detergent for about 20 minutes. Following a second rinse, the unit was shut down.

The Dairy Research and Development Corporation Whey Utilization Project

R. W. Bond

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The Dairy Research and Development Corporation (DRD) was awarded a Federal Water Pollution Control Administration Project on December 19, 1968. The title of the project is "Elimination of Pollution by and Utilization of Protein Concentrates (Dried Whey) from Milk Residues of Cheese Making." The project site is Vernon, N. Y. The project number is 12060 DEQ WPRD 219-01-R1. The description of the project is "A development and full-scale demonstration of a process for the conversion of dairy whey into salable food products by evaporation and spray-drying methods. The conversion of whey to a usable food product in lieu of its disposal as a waste product from cheese manufacture is the pollution abatement method to be developed and demonstrated. Research will be conducted on the use of dried whey as a supplement to various food products."

The Dairylea Cooperative, Inc., plant at Vernon was selected as the site for this project. The plant is located in a milk-producing area, and its managers are progressive thinkers who desired to participate in the project to eliminate the pollution potential of a large cottage cheese plant. After a great deal of investigation, consultation and study, dryers made by the DeLaval Separator Company were selected as the best suited for drying acid whey to a nonhygroscopic food-grade powder.

During 1970, Dairylea built the building required for the drying equipment and packaging facilities. DeLaval installed the original basic process equipment in that year.

During 1971 and the first quarter of 1972, the process was developed and the equipment modified. We conducted laboratory experiments, partial or single-step plant-scale experiments, and full-process experimental runs. This phase of a development is generally time-consuming, and this project was particularly long. As those of you who have had experience with drying whey know, this product has some undesirable characteristics that are difficult to control. Progress was further impeded because there is no way to obtain a product for subsequent process evaluation with a physical nature duplicating that produced by spray drying other than to run the spray dryer. Further, we encountered conditions that gave us what appeared to be good spray-dried products but an intolerable tackiness in the dust which caused a build-up on the walls of the dust system.

In the course of this development, the results we obtained dictated changes in the basic equipment. A few examples of the equipment changes were the substitution of vibrating conveyors for belt conveyors, removal of air-lock valves from high-moisture product cyclone discharges, and complete redesign of the air discharge from the spray dryer.

In developing a commercially feasible process for the conversion of acid whey to a food grade nonhygroscopic powder, we found the following processing steps or conditions to be critical:

Handling of raw whey.

Evaporator conditions.

Solids content of concentrated whey.

Lactose crystallization in concentrated whey.

Nozzle and air pattern in spray dryer.

Temperature of spray dryer discharge air.

Moisture content of product from the spray dryer.

Moisture content of secondary dryer product.

Crystalline lactose content and type in the final product.

Product moisture-air temperature relationship at each point of the process.

I am pleased to be able to report that we at DRD have developed commercially feasible operating conditions for the production of a food-grade, nonhygroscopic acid whey powder in the Vernon equipment. I do not mean to imply that we are completely satisfied with our present operation. We are making several more equipment changes before making products for our marketing program. Experience has made me a firm believer in the learning curve. You can expect an increase in learning rate, increased production rates, and/or reduced total costs as you gain operating experience. I am confident there will be many more changes in processing as this portion of the dairy industry is developed.

The last phase of this project is the marketing of the whey powder. This is a challenge because whey has been looked upon as a waste. There have been some poor-quality products offered which gave all whey products a bad name. We are coming into the market at a period when labeling requirements are becoming more stringent, food faddists are active, and other conditions are causing rapid changes in our industry.

Whey is a natural base product of high nutritional value and contains many components for which there is a current demand in the food industry. Another industry has been faced with a strikingly similar problem and has converted wastes into high-profit products. We must likewise establish a profitable market for whey as a food ingredient.

In closing, I would like to thank all the members of the Environmental Protection Agency, the U.S. Department of Agriculture, Cornell University, DeLaval Separator Company, Dairylea, and others in the dairy industry who have assisted the DRD Corporation on this project.

Whey Processing Progress in Other Countries

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and

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Mr. Horton:

I am able to report that a great deal of progress in the processing of whey is being made outside of the United States. To review this progress in detail, I have prepared a summary of statistics for the major cheese- and casein-producing countries in several geographic areas of the world. The statistics will be given in billions of pounds of whey and are based on United Nations publications showing cheese and casein production data. The statistics for each area will serve as a background for comments I will offer on the status of whey processing. We will see that developments outside of the United States are proceeding at a faster pace than here at home, partly due to pollution problems, but more importantly because of the desire to take advantage of the unique values of whey solids.

Oceania and Japan. I begin our worldwide survey at a distant place, to present what will be a high point of this conference: a summary description of a sanitary, cleaned-in-place, low-pressure commercial plant for whey ultrafiltration by Dr. K. J. Kirkpatrick of the New Zealand Dairy Research Institute (NZDRI).

To preface Dr. Kirkpatrick's remarks, we will look at the whey production statistics for New Zealand, Australia, and Japan. The production of these countries is brought together in table 1 because of their mutual Far Eastern location and because Japan buys a significant portion of the milk products from New Zealand and Australia.

Several important points relative to these three countries are offered as further background:

1. Australia increased casein production through last year, while New Zealand curtailed production sharply. The increasing world price of nonfat dry milk and the resulting value of return on milk solids had a major influence on the casein situation in New Zealand. A drought in 1970 and 1971 also affected production.

2. The price of casein may be showing signs of dropping and could affect production.

3. Japan's rapid development of a dairy industry and an accompanying rapid rise in production of cheese as a source of protein may be limited by land required for grazing, unless confined feeding practices are adopted.

4. Severe water pollution problems in Japan are bringing about tough pollution control laws, with obvious effects on cheese and whey plants.

5. One of the three major milk companies in Japan now offers electrodialysis and spray-drying equipment for sale on the world market following development for internal use.

6. The State of Victoria in Australia has formed an association of casein and cheese manufacturers to cope with an urgent need for processing whey brought about by nearly total wastage of whey and enforcement of new strict pollution laws. Results of early progress will be covered after Dr. Kirkpatrick's talk.

7. Evaluation of reverse osmosis (RO) and ultrafiltration (UF) by a private company in New Zealand four years ago, independent of the work by the NZDRI, reflects the importance of the dairy industry there and the willingness to innovate to yield higher returns on milk solids.

TABLE 1.--Cheese and casein whey production in Oceania and Japan

Country	Billions of pounds[1]		
	1968	1969	1970
Oceania			
New Zealand	3.50	3.40	2.05[2]
Australia	2.01	1.94	2.06
Japan	0.65	0.75	0.80

[1]Values assume 9 pounds of whey per pound of cheese or casein.

[2]Cheese whey only.

New Zealand. Now I would like to introduce Dr. Kirkpatrick. He did his graduate and undergraduate work in chemical engineering at Canterbury University in Christchurch, New Zealand. He has been active in the application of membrane separation processes to dairy products for three years at the NZDRI and is now directly responsible for these activities. His group supports the adoption of UF and RO on a commercial scale in cooperative dairy companies throughout the country.

Dr. Kirkpatrick:

First let me say as a visitor to this country how welcome I have been made to feel wherever I have been. Thank you for your hospitality.

After listening to the papers already presented at this conference, it is clear that we have interests in common in the whey processing field, and that there is much to be learned from your experience and the excellent work that is in progress in this country.

It may be useful to sketch quickly the organization of the dairy industry in New Zealand before going into detail about UF. In New Zealand the fluid milk and manufacturing dairy industries are quite distinct from each other. The manufacturing industry is much the larger of the two since New Zealand's population is just under three million. Most of the production is destined for export in the form of a wide range of dairy products.

The manufacturing dairy industry is organized on a wholly cooperative basis and only farmer suppliers to a company can be shareholders in that company. On a national scale, and for dairy industry purposes, the country is divided into a number of regions, each of which elects a representative farmer to the New Zealand Dairy Board, which maintains offices in Wellington, the capital city. The Dairy Board, through its executive staff, administers all of the activities of the New Zealand Dairy Industry.

The NZDRI, for which I work, is an independent body funded partly by the Dairy Board through a levy on products and partly by government grant. It functions as the central research facility for the manufacturing industry. As a generalization, its interests start outside the farm gate and center particularly on the fundamental and applied aspects of processing and manufacturing operations. The staff is about 150, approximately 50 of whom are university graduates in a variety of scientific and technological disciplines.

Organizationally, the work of the institute is divided into the broad classifications of fundamental and applied. Within each division a number of sections have been formed to deal with specific areas of work. For example, in the fundamental division there are sections dealing with biochemistry, microbiology, flavor, protein chemistry, and so on, while in the applied division there are product-oriented sections such as butter, milk powders and drying, caseins, whey products and ultrafiltration.

Just under three years ago the institute began a general study of the possible uses of membrane processing in dairy manufacturing operations. A program of pilot-scale investigation of ultrafiltration of acid casein whey was set up shortly afterwards. I should explain that acid casein in New Zealand is made by the lactic process where pasteurized skim milk is inoculated with a suitable lactic culture; the whey is therefore broadly similar to cottage cheese whey with which you are all no doubt familiar. The reasons why we started with an investigation of acid casein whey were:

1. Composition and characteristics. The composition and characteristics of acid whey make it the least attractive and most difficult to manufacture into a whole whey product. Clearly, ultrafiltration offered, at the least, a path to improvement of the compositional balance.

2. Scale of operation. Casein manufacture in New Zealand is carried out in well-organized factories of such a size that sufficient whey is available in one location to make whey processing a practical possibility.

3. Acidity. Although in some ways a handicap, the acidity of the whey was thought likely to be an advantage in inhibiting microbiological deterioration during processing. It was clear at that time that ultrafiltration was going to involve a batch concentration of some hours' duration with most kinds of available equipment.

Our early experimental work was conducted using a pilot plant with a few square feet of Abcor tubular membranes.

We set out to find operating methods and conditions that would meet the following needs:

1. To retain product functionality throughout the processing. We heard yesterday of these functional properties from Dr. Morr of the University of Minnesota.

2. To maintain control over the microbiology of the whole process.

3. To find means for the cleaning and sanitizing of membranes and equipment that could be used repeatedly without an undue rate of deterioration in membrane performance.

It was recognized that membranes were basically a consumable item.

We had some initial doubts concerning the consequences of the fairly stringent limitations on exposure of cellulose acetate membranes to chemicals and high temperature. These restrictions, however, have not proved a serious handicap, with the Abcor equipment, in finding workable operating methods.

In general the operating conditions that were found satisfactory in pilot operation are similar to those currently suggested by most membrane plant manufacturers. Flux increases with temperature, and above about 30° C., microbiological growth rate is reduced; but above about 55° C., loss of product functionality is at a higher risk and membrane life is probably reduced.

Cleaning and sanitizing could be satisfactorily effected with the now-familiar combination of enzyme detergent and controlled use of chlorine sanitizers.

It became evident that the beguiling simplicity of the concept of membrane processing--a simple matter of hydraulic pressure causing permeation--concealed a few traps for the unwary. Nevertheless, problems were overcome, and on the basis of the research a decision was made by the New Zealand Co-op Dairy Co., our largest cooperative, to purchase a commercial Abcor ultrafiltration plant. Design capacity was 400,000 pounds/day.

We have therefore had some months of operational experience in processing lactic casein whey on a commercial scale. Design capacity of the plant has been readily achieved and equipment performance and reliability have been satisfactory.

Restoration of plant flux by daily detergent cleaning and sanitation by standard procedures have been effectively achieved in practice. Where circumstances led to a deterioration in the sanitary status of the plant, it proved possible to restore the plant to a completely satisfactory level of operation.

Some progressive loss of flux has been noted, but a one-year operational life for membranes appears entirely feasible.

To summarize: In spite of a number of teething troubles, the outlook for ultrafiltration of acid whey is encouraging.

Mr. Horton:

Australia. In Victoria, Australia, over half the whey in the country is produced, and the disposal of hydrochloric acid casein whey is especially troublesome. Two government research organizations are providing valuable product assistance to the whey utilization association that has been formed to resolve whey processing and disposal problems.

The Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Victoria Department of Agriculture are cooperating on the application of ultrafiltration to casein and cheddar cheese wheys. In personal communications, L. L. Muller and J. F. Hayes, of the Division of Food Research, CSIRO, and Dr. A. T. Griffin, of the Victoria Department of Agriculture, have described to me the as follows the interesting behavior they have observed in these wheys:

"Comparative studies are in progress on both types of whey processed with a range of UF module designs including both cellulose acetate and non-cellulosic membranes. For microbiological considerations, most studies have been with whey at about 50° C.

"Preliminary observations using an experimental hollow fibre unit with non-cellulosic membranes illustrated the differences between the two whey types. The flux rate for Cheddar cheese whey at pH 6.0 was about double that for HCl casein whey at pH 4.3. Similar differences between the two types of whey were later obtained with modules from Abcor, Inc., and Patterson Candy International (cellulose acetate) and from Amicon Corporation (thin channel module, copolymer type membranes).

"One obvious difference between the two types of whey was their pH. When the nitrogenous substances of the wheys were fractionated at varying pH values on Sephadex G100 gel, a change in distribution of the peaks was observed if the pH was 3 or below or above 8. In both cases a single peak replaced the two peaks of beta-lactoglobulin and alpha-lactalbumin.

"The behaviour of the wheys at various pH values on the hollow fibre unit was therefore examined. The comparative results for steady flux rates during recirculation, on the basis of 100 units for Cheddar cheese whey at pH 6.0, are as follows:

pH	Cheddar Whey	HCl Casein Whey
7.2	125	70
6.0	100	-
4.3	40	56
2.9	120	110

"Variations with pH of a similar order of magnitude have been found with the 3 other types of UF modules studied to date.

"The effect of pH on the behaviour of whey on Sephadex gel suggested that the main influence of pH on flux rates during ultrafiltration would be associated with the state of aggregation of the proteins. This suggestion was supported by the observation that the major increase in flux rate at low pH occurred only if the pH was 3.0 or below. The change in peaks on Sephadex followed the same pattern. However, the differences in flux rates between the two types of whey at pH values around 7 indicate that factors other than the effect of pH on the proteins may also be involved. Other possibilities are being explored."

Messrs. Muller and Hayes and Dr. Griffin also indicate that much larger quantities of whey are being produced in Australia than are shown in table 1. They put the production at about 3.2 to 3.5 billion pounds annually, over half of it in the form of hydrochloric acid casein whey. They say about 70 percent of this total whey is produced in the State of Victoria, the main manufacturing area for casein, where the proportion of this type of whey is even higher.

Looking forward to a widening range of human food uses for whey protein concentrates to be recovered in UF plants such as the one described by Dr. Kirkpatrick, Dr. Griffin has formulated yoghurts using whey protein concentrates (WPC) to replace skim milk powder (nonfat dry milk). Table 2 shows a series of trial formulations. Two taste panels evaluated these formulations and also compared them to a commercial "natural" yoghurt. Formulations

TABLE 2.--Formulations with whey protein concentrate (WPC) added to milk for yoghurt manufacture

Formulation	Additional whey protein supplied by:	
	Skimmilk powder (grams/liter)	Liquid or powder WPC[1] (grams/liter)
1. Whole milk + 5 percent milk powder	2.63	0.00
2. Whole milk + 2.5 percent milk powder + 1 pint liquid WPC	1.32	1.22
3. Whole milk + 2 pints liquid WPC	0.00	2.41
4. Whole milk + 4 pints liquid WPC	0.00	4.83
5. Whole milk + 2.5 percent milk powder + 3 oz. powder WPC	1.32	1.20
6. Whole milk + 6 oz. powder WPC	0.00	2.41
7. Whole milk + 12 oz. powder WPC	0.00	4.80

[1] Protein content approximately 5 percent for the liquid and 55 percent for the powder.

2 and 5, employing either liquid or powder WPC to replace one-half of the skim milk powder were rated equal or superior to the control (Formulation 1) and the commercial yoghurt.

After four days of storage and one day of transport, followed by overnight storage, duplicate samples of the formulations were opened to test their keeping quality. Formulations 6 and 7 had a "shattered" body and thus excessive whey. Formulations 1, 3, and 4 showed excessive whey on the surface. Formulations 2 and 5 again showed superior qualities imparted by the WPC, having no defects in body.

In terms of consumption of whey proteins, yoghurts represent a much more likely outlet here than in Australia, so we are especially indebted to this development. Cottage, cream, and farmer cheese producers serving areas of the United States where yoghurt sales are highest should take special note.

Australia is also tackling the problem which gives all of us concerned with the fractionation of whey the severest headache--the utilization of all the lactose "liberated" by ultrafiltration of whey proteins. In past years, the Division of Chemical Engineering of CSIRO has carried out a number of economic studies of whey processes such as drying and fermentation. Emphasis is now on development of data essential to the successful use of reverse os-

In South America, whey is fed to pigs or is wasted. In Argentina, the major producing country, the use of reverse osmosis for concentration may be attractive because of the many small plants there. Consolidation of these plants is expected to take place eventually in keeping with the same trend elsewhere in the world.

Western Europe. Utilization of whey is highly developed in most of the Western European countries, though the most significant use is in animal feeding.

In France, whole whey is generally dried if used at all, though the SAV yeast fermentation process has been in use for some time. (SAV is a continuous fermentation which uses a mixture of microorganisms to deplete partially the lactose and lactic acid in whey. The initial product contains both yeast and lactose in about the same proportions.) In Italy, much whey is still reportedly wasted or fed to pigs, and whey is a serious polluter of waters in the dry, southern half of the country. Rivella, a whey-based drink now being market tested here, is reported to be the most popular soft drink in Switzerland. It is also being made in The Netherlands.

Table 4, summarizing whey production in Western Europe, indicates that countries such as France, with quantities of whey approaching ours, but with much less land area, are likely to be particularly sensitive to the pollution issue.

TABLE 4.--Cheese and casein whey production in Western Europe

Country	Billions of pounds		
	1968	1969	1970
British Isles			
England, Scotland and Ireland	2.95	3.00	3.20
Continent			
France	14.60	14.80	14.90[1/]
West Germany	8.60	9.30	9.90
Italy	9.30	9.20	9.10
Netherlands	4.80	5.20	5.50
Spain	1.90	2.10	2.10
Switzerland	1.70	1.65	1.70
Scandinavia			
Denmark, Finland, Norway and Sweden	4.85	5.00	5.10

1/ Cheese only.

mosis, crystallization, etc. Dr. Otto Sitnai sent to me a personal communication on studies of crystallization of lactose from the permeate coming from ultrafiltration. The objective of the work is to make attractive the sale of lactose by factories with less than 300,000 pounds of whey per day. Concentration of the lactose solution by reverse osmosis with membranes of varying tightness is being carried out to achieve higher lactose purities prior to crystallization. Model solutions as well as UF permeate are being used to define factors limiting crystallization rates. Methods of improving these rates will be developed. Four or five people are assigned to this task, indicating Australia's recognition for speed in resolving whey processing alternatives.

North and South America. Returning closer to home, we see from table 3 that Canada has 10 percent of the whey quantities found in the United States. The production is divided nearly equally between Quebec and Ontario, with the other provinces producing much lower, though no less troublesome, quantities. Consolidation of cheese operations, stepped-up pollution control laws, and the possibility of a major whey-processing project in Quebec indicate extensive attention to the whey problem. The dry plains provinces are experiencing greater pressures to curb pollution because water is just that much more precious. While extensive spray drying of whey exists in Canada, still much is wasted.

TABLE 3.--Cheese and casein whey production in the Western Hemisphere

Country	Billions of pounds[1/]		
	1968	1969	1970
North America			
United States	24.6	25.0	25.4
Canada	2.22	2.31	2.28
South America			
Argentina	3.87	3.87	3.76
Brazil	0.91	0.96	0.99

[1/] Values assume 9 pounds whey per pound cheese and casein except for U.S. where a smaller quantity was used to account for cottage cheese.

Interest in the newer processes is at its highest in Western Europe, with emphasis on protein recovery and with several companies offering UF and RO equipment in varying stages of development.

Several universities and government research centers are especially active in the development of UF and RO for dairy products. Sufficient good experience exists to permit a shift of current emphasis from whey to the processing of skim milk by UF for cheese making.

In 1972, it is expected that UF and RO will be applied to whey on a commercial scale in Denmark, France, and Germany.

In 1973, UF and RO should also be in commercial use in Italy, and perhaps England, Ireland, and Spain.

Electrodialysis, used successfully here for years to produce demineralized whey products, is now finding increasing use throughout Europe; new plants are under construction in several countries. The use of RO for concentration ahead of electrodialysis is now of interest.

Eastern Europe. Table 5 shows that large quantities of whey are produced in the eastern portion of Europe, which I have taken here to include Greece and Yugoslavia as a simple geographic (rather than political) division.

TABLE 5.--Cheese and casein whey production in Eastern Europe

Country	Billions of pounds		
	1968	1969	1970
U.S.S.R.	9.60	9.90	10.50
Poland	4.25	4.45	4.60
Bulgaria	0.69	0.71	0.74
East Germany	1.15	1.20	1.25
Greece	2.45	2.55	2.70
Yugoslavia	2.00	2.00	2.00

Aside from whey fermentation work in Czechoslovakia and the development of whey "champagne" in Poland, little is published about the current habits of disposing of or utilizing whey in Eastern Europe. One assumes that hogs, rivers, or sewers are the recipients.

An unconfirmed rumor has been circulated that a UF plant is being built in Bulgaria. This particular rumor is especially enjoyable to me because visiting this plant would be even a tougher proposition than visiting the UF plant described by Dr. Kirkpatrick. On that note, being a prejudiced believer in UF and RO, and hardened by rumors, I close and thank you.

Closing Remarks (Luncheon Address)

Howard S. Gochberg

President, Whey Products Institute
Land O'Lakes, Inc.
Eau Claire, Wis. 54701

It is both my pleasure and privilege to share with you a few observations and thoughts in concluding the program of the Whey Products Conference/1972 as cosponsored by the Whey Products Institute and the Eastern Marketing and Nutrition Research Division of the U.S. Department of Agriculture.

Firstly, your individual and collective attendance, over 300 registrations, at this conference is most gratifying and reflects so well the intent of the whey manufacturers, government, universities, and interested allied industries in establishing a rightful and proper place for whey and whey products as economical, nutritious, and functional dairy products--and not as dairy waste disposal products. Keep in mind the words "economical, nutritious and functional dairy products." Those words, in my opinion, make for a most important distinction for the progress and profit future of the whey processing industry in the years to come.

I think we can all agree that the conference program has very well developed in scope and has proved comprehensive in subject matter. Program speakers have reviewed the present status of a number of whey industry developments and have set desirable goals and objectives for the future.

The conference included a panel of knowledgeable speakers who addressed their remarks to the matter of "utilization" of whey, and this represents an appropriate step in the right direction. Perhaps I should say a "needed" step rather than an "appropriate" step. Thus far, whey manufacturers have been oriented to production or processing techniques. Unquestionably, this was advisable, for there were, and are, large volumes of dairy whey containing highly desirable quantities of protein, lactose, minerals, and water-soluble vitamins of milk. Production techniques have been and are being developed to recover these highly valuable milk nutrients from the whey. But market development or utilization of dry whey and the products of whey has not kept pace with product production. We are not processing the available whey supplies! So obviously, as an industry, we have our work cut out for us in the matter of developing markets of utilization, be they human food, animal feed, or industrial.

The Whey Products Institute (WPI) is actively engaged in developing a program for compiling data on market development and utilization, along with standards of identities and product specifications for dry whey products. And we will be seeking the cooperation of the USDA and FDA in these matters, which are very important to the progress of the industry and to the acceptance of our products by consumers. These particular WPI activities in the specification and standards area are basic since no markets can be served satisfactorily unless the products are of uniform high quality. That is the keystone of sales success, whether it be dry whey or any other product of commerce. Furthermore, the attainment of successful, expanding, and profitable sales will require a substantial effort involving imaginative research marketing and processing along with a consistency of purpose on the part of each whey product manufacturer. Bear in mind, the individual manufacturer, whether he be large or small, prospers as does the industry of which he is a part.

Again, let me say that the interest you have displayed by attending this conference is sincerely appreciated. We are confident you found it very worthwhile and indicative of the work underway to establish due recognition of dry whey products as economical, nutritious, and functional dairy foods.

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Green Giant Company Le Sueur, Minn. 56058	-Bill Stoll
Halwin Dairy Products 129 The Lane Hinsdale, Ill. 60521	-Harold Brackett
Hillfarm Dairy Jewel Company 1955 W. Worth Ave. Melrose Park, Ill. 60160	-Donald F. King Ed Grody
H. P. Hood & Sons 500 Rutherford Ave. Boston, Mass. 02129	-W. Kneeland S. L. Lauderbach
Impact 7 Box 335 Turtle Lake, Wis. 54889	-James L. Ray
Industrial Food Materials, Inc. 150 Main St. Peabody, Mass. 01960	-Ralph C. Zalkan
Institute of Food Technologists 221 N. LaSalle St. Chicago, Ill. 60601	-John B. Klis
Ionics, Inc. 65 Grove St. Watertown, Mass. 02172	-William Iaconneli
Iowa State University Dept. of Food Technology 1407 McKinley Drive Ames, Iowa 50010	-V. H. Nielsen Earl O. Wright
Jack Frost & Associates 4365 Province Line Rd. Princeton, N. J. 08540	-Jack Frost

Organization	Name
Kansas State University Department of Dairy Science Manhattan, Kansas 66502	-J. L. Morrill
Kenics Corporation 619 E. Main St. St. Charles, Ill. 60174	-Horace F. Morgan
Knudsen Corp. P. O. Box 2336 - Terminal Annex Los Angeles, Calif. 91105	-M. Blank Bromley M. Mayer
Kraftco Corp. Research & Development Division 801 Waukegan Rd. Glenview, Ill. 60025	-Martin Engel Eugene P. Kolen O. J. Krett A. D. Singleton
Kraft Foods 500 Peshtigo Court Chicago, Ill. 60611	-Stanley M. Osri
The Kroger Company 1240 State Ave. Cincinnati, Ohio 45204	-J. A. Cornett Donald Vell
Lactantia, Ltd. C/P. 457 Victoriaville, Canada	-Nguyen Cong-Thanh
Lactose Co. of New Zealand, Ltd. Manair Road, Kapuni Taranski, New Zealand	-John M. Wood
Land O'Lakes, Inc. 614 McKinley Place Minneapolis, Minn. 55413	-Gint Behrens Fred Friedrich Ray Mykleby
	Howard S. Gochberg 1243 N. Eleventh St. Eau Claire, Wis. 54701
LeSueur Creamery, Inc. 119 N. Front St. St. Peter, Minn. 56082	-Stan Davis
Lockwood Greene Engineers, Inc. 391 Vesta Court Ridgewood, N. J. 07450	-Charles M. Good

Organization	Name
Lynn Proteins, Inc. R. 1 Granton, Wis. 54436	-W. W. Schwantes
Manitoba Development Corp. 600-428 Portage Ave. Winnipeg, Manitoba, Canada	-Charles Norman
Maple Island, Inc. 2815 Blaisdell Ave., S. Minneapolis, Minn. 55408	-Glenn Newcomb
Marriott Walker Corp. 925 E. Maple Rd. Birmingham, Mich. 48011	-Oscar D. Turner
Maryland & Virginia Milk Producers Association	-C. I. Horrocks Box 184 Laurel, Md. 20810
Mississippi Valley Milk Producers Association	-Leon K. Olson Highway 18 & 52 Luana, Iowa 52156
McGraw-Hill 645 N. Michigan Chicago, Ill. 60611	-M. Sheldrick
Arthur G. McKee & Co. 10 S. Riverside Plaza Chicago, Ill.	-J. Janak
Mead Johnson & Co. 5400 N. Kerth Evansville, Ind. 47711	-Robert G. White
Meinerz Creameries, Inc. 2200 S. 170th St. New Berlin, Wis. 53151	-Bernard J. Meinerz
Michigan State University Dept. of Food Science & Human Nutrition East Lansing, Mich. 48823	-Ted Hedrick A. L. Rippen Charles M. Stine
Mid-America Dairymen, Inc. P. O. Box 1837, S.S.S. Springfield, Mo. 65805	-L. Claypool Jim Garrison Burdet Heinemann

Organization	Name
Mid-America Dairymen, Inc. (cont'd)	Worth Genck 350 Endicott on 4th Bldg. St. Paul, Minn.
Mid-West Producers Creameries, Inc. 224 W. Jefferson South Bend, Ind. 46601	-Chet Koza
Milbrew, Inc. 330 S. Mill St. Juneau, Wis. 53039	-S. Bernstein T. C. Everson
Miles Laboratories	-D. Hupp 1127 Myrtle St. Elkhart, Ind. 46514 Harold Rapp R.R. 7, Box 550 Elkhart, Ind. 46514
Milk Specialties, Inc. P.O. Box 278 Dundee, Ill. 60118	-Richard Janita V. W. Nielsen
Ministry of Agriculture & Food Milk Commission c/o Parliament Bldg. Toronto 182, Ontario Canada	-R. H. Jardine
Mississippi Valley Milk Producers	-Earl Green 115 N. Jones Ave. Maquoketa, Iowa 52060 Alan Rueter Box 345 Postville, Iowa 52162
Mojonnier Bros. Co. 4601 W. Ohio St. Chicago, Ill. 60644	-John J. Mojonnier Eugene F. Juhrend David Berks 1525 Glenwood Ave. Minneapolis, Minn. 55405
Mora Industries 999 E. Maple St. Mora, Minn. 55051	-E. A. Huber D. J. Sweeney

Organization	Name
Nauvoo Milk Products, Inc. P.O. Box 188 Nauvoo, Ill. 62354	-R. A. Falk
New Zealand Cooperative Dairy Co., Ltd. P.O. Box 459 Hamilton, New Zealand	-Jeffrey Jackson Roy Leighton
New Zealand Dairy Board P.O. Box 417 Wellington, New Zealand	-Andrew Flower D. W. King
New Zealand Dairy Research Institute Palmerston, North, New Zealand	-James A. Kavanagh K. J. Kirkpatrick
New Zealand Milk Products 6300 N. River Road Rosemont, Ill. 60018	-N. O. Jones
North Carolina State University P.O. Box 5992 Raleigh, N. C. 27607	-W. Roberts
Northland Foods 116 N. Main St. Shawano, Wis. 54166	-D. R. Braatz Carl Wilkey
Ohio State University 2121 Fyffe Rd. Columbus, Ohio 43021	-W. James Harper
Oscar Mayer & Co. Box 1409 Madison, Wis. 53716	-George W. Evans
Paniplus Company 3406 E. 17th St. Kansas City, Mo. 64127	-M. S. Cole
Pepsi Cola Company 46-00 5th St. Long Island, N. Y. 10001	-P. Amonick
Pharmacia Fine Chemicals, Inc. 800 Centennial Ave. Piscataway, N. J. 08854	-Tim Horton

Organization	Name
The Pillsbury Company 311 Second St., S.E. Minneapolis, Minn. 55414	-Reginald E. Meade
Pollio Dairy Products Wolf Run Road Campbell, N. Y. 14821	-Robert Russo
Jules Porsche & Associates 138 Oxford Ave. Clarendon HIlls, Ill. 60514	-J. Porsche
Precision Foods Co. 300 W. First St. Waconia, Minn. 55387	-Merton Cooper
Preferred Milks, Inc. 1524 W. Germak Chicago, Ill. 60608	-D. M. Kelly, Jr.
Procter & Gamble Co.	-David E. O'Connor 6071 Center Hill Rd. Cincinnati, Ohio 45224 Richard M. Roudebush 8912 Monsanto Drive Cincinnati, Ohio 45231
Purity Cheese Co. Box 27 Mayville, Wis. 53050	-D. C. Kolpack Ken Royer J. R. Scheder R. S. Villars
Ralston Purina Co. 901 Checkerboard Square Plaza St. Louis, Mo. 63188	-R. H. Arndt J. M. Dunker C. W. Kolar R. K. Kuelpman
R. J. Reynolds Research Dept. Winston-Salem, N. C.	-G. M. Sawyer
Rivella International 11 Colonial Way Weston, Mass. 02193	-Frederick C. Kulow
C. E. Rogers Company South Highway 65 P.O. Box 118 Mora, Minn. 55051	-Burton Henris Harlan Talley

Organization	Name
Ross Laboratories 625 Cleveland Ave. Columbus, Ohio 43216	-Larry Criswell
Rutgers University Department of Food Science New Brunswick, N. J. 08903	-Joseph G. Leeder
Safety Industrial Solvents & Chemical Corp. 6915 W. Capitol Drive Milwaukee, Wis. 53216	-Earl Seefeldt
Safety Stores 2538 Telegraph Ave. Oakland, Calif. 94612	-Dee R. Morgan
Schipke Engineers 3101 W. 69th St. Minneapolis, Minn. 55435	-Joseph A. Perry
A. D. Seidel & Son, Inc. 2323 Pratt Blvd. Elk Grove Village, Ill. 60007	-A. B. Habighurst
Sheffield Chemical 2400 Morris Ave. Union, N. J. 07083	-William D. Milford
Silverwood Industries Box 2185 - Terminal A. London 12, Ontario, Canada	-Bram M. Perzow
Snow Brand Milk Products Co., Ltd. 3333 Henry Hudson Parkway, Riverdale New York, N. Y. 10463	-Akira Moriyama
South Dakota State University Dairy Science Department Brookings, S. D.	-J. Parsons S. Seas Kenneth R. Spurgeon
Stauffer Chemical Co. Energy Products Dept. 7505 Washington Ave., S. Edina, Minn. 55435	-A. Cater J. Feminella
Swan Enterprises 4223 Center St. Omaha, Nebr. 68105	-Robert Olson

Organization	Name
Swift Chemical Co.	-Jeffrey L. Pochop 115 W. Jackson Blvd. Chicago, Ill. 60604 David M. Miller Jordan Rd. Hart Lot, N. Y. 13075
Tailor & Co. 2403 State St. Bettendorf, Iowa 52722	-John P. Tailor
Tennessee State University 3500 Centennial Blvd. Nashville, Tenn. 37203	-Roland Norman
Trugman-Nash, Inc. 105 Hudson St. New York, N. Y. 10013	-Solomon Silberman
Twin Dakota Dairy Greenwood, Wis. 59437	-Frank Thomas
(no company listing)	-F. E. Uetz 395 Maitland Ave. Teaneck, N. J. 07666
Ulvac Corp. 1-1 Kyobashi Chuo-Ku Tokyo, Japan 104	-Koichi Hashimoto
Union Carbide Linde Division P.O. Box 44 Tonawanda, N. Y. 14215	-Charles S. Carroll
Universal Oil Products Algonquin & Mt. Prospect Rds. Des Plaines, Ill.	-Ken Anderson
University of Alberta Department of Food Science Edmonton, Alberta, Canada T6G2E1	-L. F. L. Clegg C. Gail Stinson
University of California Department of Food Science & Technology Davis, Calif. 95616	-W. L. Dunkley

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University of Georgia Dairy Science Building Athens, Ga. 30601	-Morrison Loewenstein
University of Illinois 1719 McDonald Drive Champaign, Ill. 61820	-J. H. Hetrick
University of Minnesota Department of Food Science St. Paul, Minn. 55101	-Charles V. Morr Stanley H. Richert
University of Tennessee Dairy Department Knoxville, Tenn. 37901	-B. J. Demott
University of Vermont Burlington, Vt. 05401	-K. M. Nilson
University of Wisconsin	-C. H. Amundson 310 Campbell St. Madison, Wis. 53711
	Kent E. Ekstrom 816 F. Eagle Hts. Madison, Wis. 53705
	Frank Groves 350 Agriculture Hall Madison, Wis. 53706
	Floyd C. Olson 505 N. Midvale Blvd. Madison, Wis. 53705
	-George W. Fry C&MS Dairy Division Washington, D. C. 20250
	Roland S.Golden AMS Dairy Division Standardization Branch, Rm. 2945 Washington, D. C. 20250
	Robert R. Miller ERS/ESAD 500 12th St., S.W., Rm. 109 Washington, D. C. 20250

Organization	Name
U.S. Department of Agriculture (cont'd)	C. H. Gordon Animal Science Res. Division Agricultural Research Service Beltsville, Md. 20705
	M. J. Pallansch John Alford Eugene J. Guy Virginia H. Holsinger Frank E. McDonough Eastern Marketing & Nutrition Research Division Agricultural Research Service Washington, D. C. 20250
	John H. Woychik Norman E. Roberts Lee P. Witnauer M. I. Wegner Howard I. Sinnamon Eastern Marketing & Nutrition Research Division Agricultural Research Service 600 E. Mermaid Lane Philadelphia, Pa. 19118
	Morris W. Sills Economic Research Service 600 E. Mermaid Lane Philadelphia, Pa. 19118
	Herbert H. Moede 809 W. Poplar Rd. Sterling, Va. 22170
U.S. Department of Health, Education and Welfare Food and Drug Administration Washington, D. C.	-Richard I. Meyer
Valley Queen Cheese Factory, Inc. 903 S. Main Milbank, S. D. 57552	-Max Gonzenbach
State of Vermont Whey Pollution Control Authority Montpelier, Vt. 05602	-Henry S. McEvoy